Journal
of
The Franklin Institute
Devoted to Science and the Mechanic Arts

Vol. 193 APRIL, 1922 No. 4

LONG DISTANCE RADIO COMMUNICATION.*

BY

L. W. AUSTIN, Ph.D., D.Sc.

Head U. S. Naval Radio Research Laboratory; Bureau of Standards, Washington, D. C.

THE distances which can be covered in radiotelegraphy have in the past always been limited mainly by the sensitiveness of the detecting apparatus, and only secondarily by the transmitting power. In the early days, when coherers were used, reliable transmission was confined to a few miles. With the discovery of the electrolytic and crystal contact detectors, the reliable range could be counted in hundreds of miles, and a somewhat uncertain communication existed across the Atlantic Ocean. This was the condition at the beginning of 1914, when the recent discovery that the de Forest three electrode audion (electron tube) was capable of producing oscillations opened a new era for radio communication. Up to that time, spark transmitting apparatus had been generally used both for the short range ship installations and for the few high-power long-distance stations then existing. The Poulsen arc giving continuous waves, in distinction from the damped wave trains from the spark, introduced about 1908, had been gradually developed so that powers of 50 KW. or more had been obtained, and a beginning had been made in the construction of high-frequency alternators, also giving undamped waves. The advantages of continuous waves, in distinction from damped

* Presented at a meeting of the Electrical Section of The Franklin Institute held Thursday, February 2, 1922.

(Note.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.)

COPYRIGHT, 1922, by THE FRANKLIN INSTITUTE.

waves, for high-power transmission were already well recognized. It was realized that, in addition to the increased selectivity in reception, the antennas required for a given transmitting antenna current could be made much smaller if continuous waves were used, and that the limitation on the possible wave-length, which existed in the case of damped waves, was removed by the use of continuous waves. The wave-length limitation for damped waves is due to the fact that the duration of the wave trains for a given decrement becomes greater as the wave-length is increased, that is, as the wave frequency is diminished, so that for a given spark frequency the successive trains approach each other and eventually overlap, thus destroying the clearness of the signal. For desirable spark frequencies, this automatically set a limit of four or five thousand metres on the wave-length.

Up to 1914 there had been no very satisfactory methods of receiving continuous waves. The customary spark receiving method could not be used because the waves were no longer divided up into trains of audible frequencies. Poulsen had placed a kind of circuit breaker, which he called a tikker, in the telephone circuit of the receiver for the purpose of breaking up the waves, and this had been improved upon and was quite generally used though far from satisfactory, since the note of the signals as heard in the telephones was not musical and could not be easily distinguished from the noises produced by atmospheric and induction disturbances. Several years before even the first experiments of Marconi, Tesla gave a marvellous series of lectures in which he pictured a system of radiotelegraphy which contained, in principle at least, almost everything which would be required for our present day radio transmission excepting the detectors and amplifiers. In these lectures Tesla proposed to receive continuous waves by making use of the audible frequency beats between two systems of waves sent out from the transmitting station at slightly different frequencies. Fessenden improved on this idea by placing the source of the second system of waves for the production of beats at the receiving station, and apparatus was actually constructed by his company in which a small arc transmitter was made to act on an ordinary spark receiving set so that undamped signals could be received on the beat principle. This arrangement, however, proved to be rather unmanageable, and it is doubtful if the beat method would have supplanted the tikker if it had not

been for the discovery of the oscillating electron tube. Like so many of the great discoveries in the history of science, the idea seems to have occurred almost simultaneously to a number of workers that the de Forest electron tube could be made a source of electrical oscillations. And nearly at the same time (1913), E. H. Armstrong in this country, A. Meissner in Germany, and H. J. Round in England, brought the idea into practical form.

Since the electron tube is able to act as a detector, and at the same time furnish its own oscillations, it at once solved the problem of beat reception in the simplest possible way.[1] With the discovery, at about the same time, that the tube was capable of amplifying weak electrical currents at either radio or audible frequencies, and that by connection of the tubes in cascade this amplification could be increased to almost any desired extent, the art of modern oral radio reception may be said to have come completely into being. The new beat method of reception has several advantages over the older method in which the electrolytic, crystal contact detector, or the non-oscillating audion were used. First, by changing the frequency of the local oscillations the note of the beats can be varied to suit the operator's ear. Second, every interfering station which is not exactly on the wave-length of the station being received has its distinctly different note. Third, the formation of beats in the receiving circuit results in currents in the receiving telephones proportional to the high-frequency currents in the antenna, while in the old detectors the telephone currents were proportional to the square of the antenna currents. The square law of response results in strong signals being very loud and weak signals very weak. In the case of atmospheric disturbances with their strong momentary peaks of intensity, this frequently results in the drowning out of the somewhat weaker signal which with undamped waves and beat reception could be easily read. Experience shows that under the ordinary conditions of atmospheric disturbance, it requires from two to four times as much current in the sending antenna to give a readable signal in the case of damped waves as with continuous waves and beat reception.

[1] For certain purposes, and especially when radio frequency amplification is used, it is found best to separate the two functions, using one tube as a detector and another one inductively coupled to the circuit as an oscillator for the production of the beats.

Recent development in transmitters has gone along three independent lines, the arc, the high-frequency alternator, and the electron tube generator. The use of the arc received a great impulse at the time of the discovery of the oscillating tube as a detector, and in spite of certain inherent disadvantages, it has come into increasing use on account of its great simplicity and reliability.

Among high-frequency alternators there are three types in use, of these the Alexanderson is employed by the Radio Corporation of America which has put them into a number of high-power stations. In France the Latour machine is coming into prominence, while in Germany the Telefunken machine is the only one of any importance, as the Goldschmidt type is, I believe, no longer used. All of these three machines are of the inductor type, the Alexanderson and the Latour machines producing the required radio frequency directly, while the Telefunken runs at slower speed, has fewer poles, and steps up the frequency by means of frequency doublers.

The third method of producing high-frequency electrical oscillations, that is, by means of the electron tube, while very commonly used for small powers, is only beginning to invade the high-power field. The English Marconi Company has recently equipped its Clifden station in Ireland with an electron tube set for communication with Nova Scotia, and its performance is stated by the company to have been extremely satisfactory.

The advantages and disadvantages of the three methods of generating continuous waves may be enumerated somewhat as follows:

The advantages of the arc are low initial cost, simplicity of manipulation, flexibility in changing wave-length, reliability, and cheapness of upkeep. Its disadvantages are a somewhat low over-all efficiency, and a somewhat impure wave which gives rise to harmonics and other disturbing emissions which cause disagreeable interference for stations working at short wave-lengths. The harmonics can, however, be largely eliminated by coupling the arc inductively to the antenna.

The alternators have the advantage of higher over-all efficiency than the arc, a purer wave, and perhaps the capability of being built in larger units and of being used in parallel for the production of very high powers. Their disadvantages are high

initial expense, and less rugged construction than the ordinary types of electrical generators. The Alexanderson and the Latour alternators have little flexibility in wave changing, while the Telefunken is limited to multiples of its initial frequency.

While our knowledge of the performance of high-power electron tube sets is very limited, they have certain qualities which seem to make them somewhat hopeful rivals of the arc and alternator. Their advantages are the highest over-all efficiency (70 per cent. to 90 per cent.), complete flexibility of wave-length change, low initial cost, and great purity of note in received signal. The disadvantages are a probable high cost of upkeep, harmonics which are considerably more objectionable than those of the alternator, and the fact that up to the present, at least, it has not been found possible to produce them commercially in units of a normal output greater than about 7 or 8 KW., although it is said that experimental tubes with an output of more than 30 KW. have been constructed.

The antennas which have been used in high-power stations are of widely different forms. It has been believed by some engineers that the Marconi bent antenna, having a length of many times its height, showed marked directive qualities so that signals could be sent in the favorable direction with much less power than with a symmetrical antenna. But the general feeling now seems to be that the directivity of the long antenna is negligible for the wave-lengths used in long-distance transmission, and that as long as the antenna has sufficient capacity for the desired currents without objectionable voltage, and has sufficient height above the ground, its shape is of no importance.

The portions of the transmitting system thus far described, the generator and the antenna, may be considered satisfactory from the efficiency standpoint, but we now come to the weak link in our transmitting system, that is, the antenna ground. In short wave stations where the power consumed in radiation is considerable, the resistance of the ground system is not of such great importance; but for long distance, long wave stations, it forms one of the two most pressing problems of radio.

Expressed in resistance, the power consumed in radiation at Annapolis, for example, at a wave-length of 17,000 metres is 0.07 ohm, while the wasteful resistance amounts to 1.6 ohms, of which a little more than 1.0 ohm is in the ground system, that is,

we have a radiation power efficiency of only 4.1 per cent. Now the power cost at a station like Annapolis amounts to approximately forty thousand dollars a year. Therefore if the ground resistance could be obliterated and the cost reduced to approximately one-third of its present amount, it would be well worth while. Then by perfectly possible reductions in other losses, the radiation efficiency could be brought to about 25 per cent., a fairly respectable figure.

Mr. Alexanderson, of the Radio Corporation, has succeeded in making a marked improvement in ground resistance in many of the Radio Corporation's stations having antennas of the long Marconi type, by introducing separate connections between the antenna and the ground at a number of points along the length of the antenna, thus dividing the flow of current and diminishing the distance which the current is compelled to traverse in the poorly conducting earth. At New Brunswick this system has reduced the antenna resistance from 3 ohms to approximately 0.25 ohm. It is, however, apparently only applicable to long, narrow antennas. It somewhat reduces the effective height, and since each of the down leads must be separately tuned, makes wave changing and retuning complicated. Very recently Doctor Meissner, of the German Telefunken Company, has announced even greater success in ground resistance reduction, which has, however, up to the present been tried out only on a small model antenna. According to Doctor Meissner's plan, buried ground wires are placed under the antenna, distributed in such a way that the amount of current collected in each ground unit is proportional to the strength of the electric field of the antenna in the given position of the unit. Return wires from the ground units are then brought back, supported on stakes to the foot of the down lead. In this way the current is taken from the ground almost as soon as it enters it, and the earth resistance is thus reduced to a minimum. By this method Doctor Meissner claims to have reduced the earth losses to approximately 0.1 ohm, and as the ground resistances of large antennas have always been found to be less than those of small ones, there seems to be reasonable hope that this radio problem will soon be solved, at least for antennas of the symmetrical types.

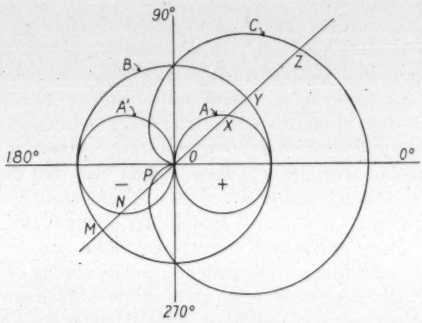
Important as the problem of ground resistance is, in the mind of the radio engineer it sinks into insignificance compared with

the supreme radio problem of the elimination of atmospheric disturbances, for on the solution of this problem the whole future of long distance radio depends. If we were freed from these disturbances we would have perfect communication with Europe, with small stations of only two or three KW., since electron tube amplifiers enable us to amplify signals to almost any extent desired, while under existing conditions stations even of a thousand KW. give far from perfect communication. I have been told that during the whole of last July the communication between two of the trans-Atlantic stations, which are considered among the most reliable, was so poor that only 23 per cent. of the words sent were successfully received.

During the last ten years a vast amount of effort has been spent on the disturbance problem. In my own laboratory alone more than one hundred distinct circuits and other devices have been tried, but for the most part with only mediocre success. It was early found that an antenna circuit of large inductance and small capacity was relatively better for receiving through disturbances than an antenna with the opposite characteristics, but the improvement due to this method is but slight. More recently it has been discovered that by the use of closed coil antennas or by the use of buried wires, the signal disturbance ratio may be improved from two to four times. The audio frequency tuning of the circuit containing the telephones also gives some improvement in the signal disturbance ratio, and is of value in reception when the incoming signals are nearly readable, but none of these methods is of any avail against such disturbances as frequently interrupt our communication from Europe during the summer months. The first substantial improvement in reception of weak signals through heavy summer disturbances resulted from the discovery during the war that the larger part of our worst disturbances came in general from the southwest, and thus by the use of a unidirectional antenna system, adjusted to receive from the northerly and easterly direction, it has been found possible at times to receive weak European stations through the most violent disturbances. These directive systems are usually made up of an ordinary antenna combined with a directive antenna such as a closed coil or a buried wire. These last receive most strongly in the direction of their length and not at all at right angles. The reception curve for the coil is shown at AA' in Fig. 1. When combined with the ordinary

antenna, which has a reception curve in the form of a circle, the combination gives a heart-shaped curve as indicated in the figure. That is to say, there is a direction just opposite the direction of maximum reception where the reception is zero. Unfortunately, however, on the Atlantic coast the disturbances at a given time do not always come from the same direction, and under these conditions our directive systems, assailed from several directions at once, no longer avail. There are, however, some favored spots on the earth where the disturbances always seem to come from the same point, so that for the reception from stations lying in a direc-

FIG. 1.



Coil and antenna reception curves.

tion not too near the direction of the disturbance centre, the problem may be considered to be almost solved.

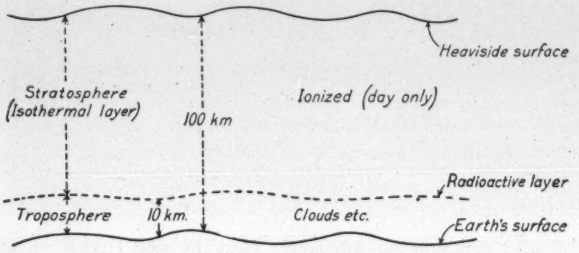
Two such receiving stations have been found, one at Goat Island, in San Francisco Bay, and the other at North Island, opposite San Diego, while it is very possible that similar conditions exist along the whole of the South California coast. But it is known that the disturbance immunity disappears as one goes north from San Francisco, since at Astoria and Bremerton the conditions are no more favorable than on the Atlantic coast. At the Goat Island station the introduction of unidirectional reception has made it possible to receive radio traffic from Cavite in the Philippines, more than 6000 nautical miles away, without interruption, except from other causes, during the worst disturbances of the past summer, instead of relaying the traffic through Hono-

lulu, as has always been necessary in the past. The antenna current at Cavite is 200 amperes and the wave-length 12,100 miles.

We do not yet know whether California is unique in possessing disturbances of such sharp directivity, but at any rate nothing of the kind has been observed elsewhere up to the present. It is evidently of the greatest importance to try to discover locations having similar qualities in regions where it is desired to establish receiving stations.

There is another radio problem which, while not as vital for practical communication as those already mentioned, is of con-

FIG. 2.



Vertical cross-section of the earth's atmosphere.

siderable theoretical interest, and of importance in the design of stations. This is the determination of the law of the transmission of the electrical waves between the sending and receiving stations.

Observations made by the Navy in 1909 and 1910 between the Brant Rock station and the scout cruisers *Birmingham* and *Salem*, and between Arlington and the *Salem* in 1912, have led to the transmission formula

$$(1) \qquad I_R = 120\pi \frac{I_s h_1 h_2}{\lambda d R} e^{-\frac{0.0015\, d}{\sqrt{\lambda}}}$$

where I_R is the current in the receiving antenna, I_s that in the sending antenna, h_1 the effective height[2] of the sending

[2] The transmitting strength of a station, provided a proper wave-length is used for the distance to be covered, is proportional to the product of the effective height of the antenna and the antenna current, usually expressed in amperes and metres. Roughly, the effective height may be taken to be 60 per cent. of the mast height. The rating, so often used, according to power or even power in the antenna, has little meaning, as a large and indefinite part of this is always wasted in the ground.

antenna, h_2 that of the receiving antenna, λ the wave-length, d the distance and R the resistance of the receiving antenna, and e the base of the natural logarithms. Here the currents are given in amperes, the distances in kilometres and the resistance in ohms. In its first form, as given after the Brant Rock tests, the formula was written

$$(2) \qquad I_R = 4.25 \frac{I_s h_s h_R}{\lambda d} e^{-\frac{0.0015 d}{\sqrt{\lambda}}}$$

where h stood for the full antenna height and a constant receiving resistance of 25 ohms was assumed. If the lengths in equation 1 are to be expressed in metres, it becomes

$$(3) \qquad I_R = 120\pi \frac{I_s h_1 h_2}{\lambda d R} e^{-\frac{0.000047 d}{\sqrt{\lambda}}}$$

and if instead of the received current, we wish to represent the electric field intensity at the receiving station, produced by the sending station, we may write

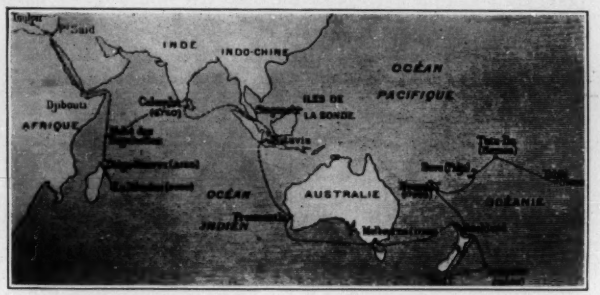
$$(4) \qquad E = 120\pi \frac{I_s h_1}{\lambda d} e^{-\frac{0.000047 d}{\sqrt{\lambda}}} \text{ Volts per metre.}$$

expressed in metres and amperes. Then the total E.M.F. on the receiving antenna would be E.h. Aside from the exponential term, equations 1, 3 and 4 are derived directly from the equations of the Hertzian oscillator, where h_1, the effective height, represents the length of one-half of the oscillator, the other half being replaced by the earth. The exponential term is empirical and takes account of the absorption of the waves in passing over the earth's surface, of the escape of energy into the upper atmosphere, and its partial reflection and refraction in the upper atmospheric layers. The constant of this term as given applies only to daylight transmission over salt water; for transmission over land the constant would have to be varied according to the nature of the country lying between the stations; while for night transmission, especially at the shorter wave-lengths the equation can perhaps not be applied at all. Even for day transmission and over salt water the formula represents only average results.

The variations in the absorption, reflection and refraction in the upper atmosphere lead to great irregularities in the intensity of the wave at the receiving station. It is known that for an

indefinite distance above 100 km. the atmosphere is permanently ionized so as to have a high degree of conductivity. Near the earth it is a good insulator, while in the region between the permanently ionized and the permanently insulating layers there are various degrees of ionization depending on the sun's rays and perhaps on direct discharges of electrons from the sun. So perhaps we may assume that the lines of electric force constituting

FIG. 3.



Route followed by the *Aldebaran*. The figures give the distances in kilometres from Nantes.

the radio waves are bounded below by the conducting surface of the earth, and above by the surface of the permanently ionized atmospheric region, while in the daytime at least there is considerable absorption in the region lying between. At night it is supposed that the lower surface of the ionized layer is fairly sharp, thus producing good reflecting conditions, and in this way giving the increase in night signal intensity generally observed. Over land where there is large earth absorption especially for short waves, the energy of these waves may perhaps travel almost entirely along the lower surface of the upper conducting region, thus giving rise to the tremendous signals often observed at short wave-lengths. It will easily be understood that the effects of all these varying conditions, the different degrees of definiteness of surface of the permanently ionized layer, various tilts to this surface, and the various degrees of ionization in the region below it will give rise to great variations in the quality of the transmission. These effects are most pronounced with the shorter waves and it may be stated roughly that, for a given distance, the

variability of the signal increases nearly in inverse proportion to the wave-length. For waves of 100 m. or 200 m. the variability is noticeable at a few kilometres, while even with waves of 10,000 m. or more very large variations are sometimes observed in the communication between America and Europe.

Since 1914 several thousand observations have been made at our laboratory in Washington on the strength of signals from the high-power European stations, especially Nauen, Germany, (6600 km.) and the average of the observed values agrees fairly

TABLE I.

Comparison of Atmospheric Disturbances, San Francisco and Washington.

SAN FRANCISCO OBSERVATIONS.

Date and time.	Direction of static.
Aug. 11: 3 P. M.	E.
Aug. 12: 10 A. M.	E.
Aug. 13: 2 P. M.	4° S. of E.
Aug. 14: 3 P. M.	E.
Aug. 16: 10 A. M.	E.
Aug. 16: 3:30 P. M.	4° S. of E.
Aug. 17: 5 P. M.	5° S. of E.
Aug. 18: 4 P. M.	9° S. of E.
Aug. 19: 3 P. M.	9° S. of E.
Aug. 20: 2 P. M.	10° S. of E.
Aug. 21: 3 P. M.	8° S. of E.
Aug. 23: 4 P. M.	2° S. of E.
Aug. 24: 1 P. M.	4° S. of E.
Aug. 25: 3 P. M.	8° S. of E.
Aug. 29: 6:30 P. M.	8° S. of E.
Aug. 30: 2 P. M.	8° S. of E.
Aug. 31: 4 P. M.	3° S. of E.
Estimated accuracy 2°-4°	

WASHINGTON OBSERVATIONS.

Direction.	Number of times observed.
W.	1
W. by S.	5
W. S. W.	25
S. W. by W.	22
S. W.	11
S. W. by S.	6
S.	4
Estimated accuracy 3°-10°	

well with the calculated values, so at present we feel sure of the approximate accuracy of the formula up to 6000 or 7000 km. But it must be remembered that the formula represents only average daylight values, and that the observations on individual days can be more than ten times either greater or less than the average, while temporary local absorption may in certain places for a period of a few hours reduce the signal to 1 per cent. or less of its normal value. This variability, even at the long wave-lengths, together with the atmospheric disturbances, constitutes the chief difficulty which at present makes absolutely continuous trans-Atlantic communication impossible. In addition to the regular observations at Washington, the Navy has also carried on many

transmission measurements at other points, extending over limited periods of time. Some of the results are shown in Table II.

The examples in this table have been chosen so as to show not only the general agreement between the observed and calculated values, but also certain exceptions. For instance, it has long been thought that the reception in San Diego from Pearl Harbor (Honolulu) is poorer than that at San Francisco, and the measurements of the receiving field at the two places support the general impressions of the operators, the observed values at San Francisco being even somewhat better than the calculated, while

TABLE II.

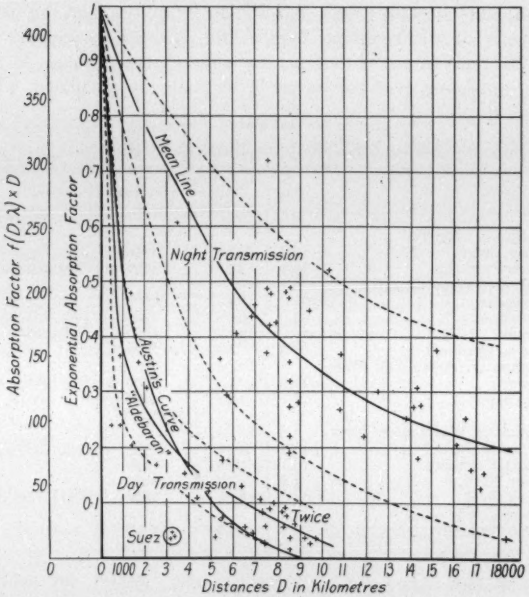
Electric Field Intensity in Microvolts per Metre.

	bs.	Cal.	Dist. Km.	
Pearl Harbor received				
at San Diego	12.1	33	4050	July, August,
at San Francisco	55.4	37	3900	Sept., 1920
Reception in Porto Rico from...				
Annapolis	192	85	2500	
Sayville	64	62	2560	Feb., March,
Darien	115	126	1800	April, 1920
Nauen, Germany	8.5	7.5	7620	
Reception at Otter Cliffs from				
Nauen	21.6	23	5700	July, Aug., 1919
San Diego	10	18.5	4450 (overland)	
Reception in Washington from				
Bordeaux (Lafayette)	46.7	31.1	6160	Aug., Sept., 1919
Nauen, Germany	10.1	12.9	6650	
Lyons, France	3.8	6	6460	
Cayey, P. R.	14	83	2590	June to Dec., 1920
Cavite received				
in San Francisco		0.60	11300	

those at San Diego are very much worse. Again, the field of Annapolis in Porto Rico is observed to be more than twice its calculated value, while the observations on Sayville, which lies nearly in the same direction and at the same distance, give almost exact agreement. This unexpectedly strong radiation from Annapolis towards the south has also been noticed and commented upon by observers in Buenos Aires. From European observations it is not thought that Annapolis radiates with abnormal strength in that direction, and it may be that Chesapeake Bay, extending to the southward, acts as a guiding conductor so that the waves are strengthened in a southerly direction.

The very low strength of field observed in Washington from Cayey, Porto Rico, only 17 per cent. of the calculated value, shows the unfortunate effects of an unfavorable situation of a transmitting station. Cayey is situated in the interior of Porto Rico and

FIG. 4



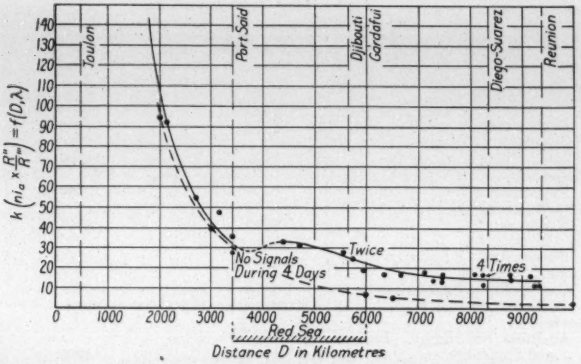
Curves for transmissions from Nantes on 9000 metres absorption factors (reduced to 1000 km.) as functions of the distance.

is almost surrounded by ranges of hills higher than the antenna which undoubtedly absorb and deflect the waves.

In 1920 the French cruiser *Aldebaran* made a voyage through the Mediterranean, Red Sea and Indian Ocean to the island of Reunion lying east of Madagascar, and then sailed eastward by way of Singapore to Australia and Tahiti. During the whole voyage, measurements were made on the strength of the signals from the French arc stations at Lyons and Nantes, measurements

in the daytime being successfully made as far as Reunion, and at night all the way to Tahiti. Aside from the large amount of radio data on the variability of signal and the differences between day and night reception at extremely great distances, a very curious deduction can be drawn from the observations in the Red Sea and in the Indian Ocean. The observed intensities follow our calculated values fairly closely as far as the Suez Canal, but after the ship entered the Red Sea it is seen that the daylight observed curves lie very much above the calculated,

FIG. 5.



Received signal strengths between Toulon and Reunion. Transmission from Lyons on 15,000 metres.

in fact the Lyons curve (wave-length of 15,000 m.) makes an actual upward bend, as shown in Fig. 5. These high observed values continue throughout the Red Sea and also in the Indian Ocean. These discrepancies led the French engineers to the conclusion that the transmission formula was not to be trusted for distances much beyond 4000 km. I believe, however, that the true explanation is the following: The Red Sea is an elongated body of salt water lying between two extensive desert regions across which the radio waves are able to move only with great energy loss. This condition of things leads to a concentration of intensity in the better conducting region of the sea, which guides the waves from the Mediterranean through to the Indian Ocean, where they again spread out as though coming from a new source.

From this standpoint it would be of the greatest interest to carry on experiments on the apparent direction of Lyons at various points in the Indian Ocean. This tendency of water to guide radio waves is well known at short wave-lengths, and especially in aircraft radio where a strengthening of signal is almost always observed when the airplane approaches a river extending in the direction of the sending station.

There are at present a number of plans for radio communication over distances much greater than those regularly covered

TABLE III.

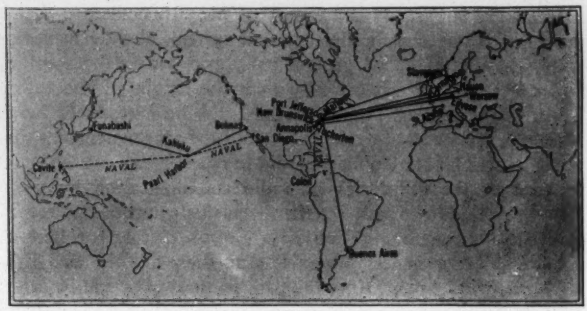
Contemplated Communications.

	Nautical Miles	Km.
Paris to Saigon	5500	10200
Buenos Aires	5950	11000
Holland to Java	6100	11300
Berlin to Buenos Aires	6400	11850
San Francisco to Shanghai	5300	9800
New York to Buenos Aires	4500	8350
Leafield (Eng.) to Capetown via Egypt	5300	9800
	In approximately	2000 mile steps
Leafield to Australia via Egypt, India and Singapore	7700	14200
	In approximately	2000 mile steps

up to the present time. The Federal Radio Telegraph Company, of San Francisco, is planning the erection of two huge arc stations at San Francisco and Shanghai, a distance of 5300 nautical miles. The towers of the new stations are to be 1000 feet in height with arcs of 1000 KW. giving antenna currents of 600 amperes or more, and with probably a wave-length of between 20,000 and 30,000 m. The problem of regular communication at such a distance is very difficult, at least in regard to the reception at Shanghai. As has already been said, San Francisco offers remarkable facilities for receiving on account of the peculiar directivity of the atmospheric disturbances which permits them to be practically eliminated in reception from the

west by unidirectional receiving apparatus. According to the transmission formula, for distances beyond 2000 miles, in order to keep up a given strength of received signal, the antenna current must be nearly doubled, that is, the power must be quadrupled approximately for every additional 700 miles of distance. The antenna current for continuous communication to Shanghai must then be, if the formula is correct at this distance, about twenty-one times that required for continuous communication from San Francisco to Honolulu, since the distance is 3200 miles greater.

FIG. 6.



American radio plans.

In addition to the decrease in average strength of signal with the distance, a great increase in variability of signal must be expected.

Another project for extremely long distance radio communication has been undertaken by the Radio Corporation of America for connecting New York with the Argentine, a distance of 4500 miles. The recently opened Radio Corporation station near Port Jefferson, Long Island, will form the New York terminal for this service, and will also communicate with points in Europe. This station when fully completed will probably be the most powerful in the world. It will be in reality twelve stations in one. The twelve antennas radiating from the central power house like spokes of a wheel are each suspended on six towers 410 feet high, carrying spreaders 150 feet long for the support of the 16 wires of the antenna. The distance between the towers is 1250 feet,

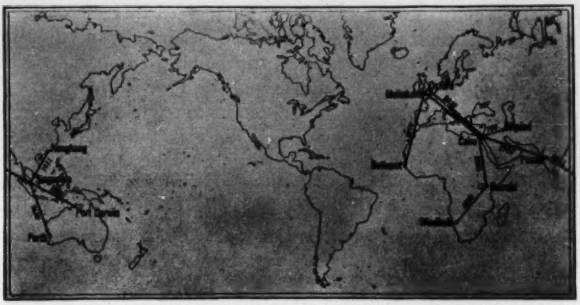
making each of the antennas about 1.5 miles long, and the total area covered by the system nearly 10 square miles.[3] It is stated that there will be ten 200-KW. Alexanderson high-frequency alternators to supply the antenna currents. It is planned to use the different antennas for separate services when transmitting conditions are favorable, but when required all can be thrown in parallel so that the power of 2000 KW. and an antenna current of 2000 or 3000 amperes will be available. At present two of the antenna units with their two alternators are in service. It will be noted that the towers are not as high as those of most of the great stations of the world, while the contemplated antenna currents are larger. It is a theory of Mr. Alexanderson that by means of his special multiple ground system, already mentioned under the discussion of ground resistance, antenna current can be increased more economically than the height of the towers. Theoretically, as has been mentioned, the field produced by the station is proportional to the product of the antenna current times the height. This station may be said to represent an extreme effort to conquer the difficulties of radio communication by power. But it remains to be seen whether even this enormous power will give constant communication with Buenos Aires, for here the conditions are even less favorable than those for the San Francisco-Shanghai circuit, since the path of the waves will lie largely over land and the direction of the atmospheric disturbances will at both ends of the circuit be unfavorable for unidirectional disturbance elimination. The receiving conditions in Buenos Aires have not in general been found very satisfactory by parties of foreign engineers who have carried on investigations there. Recently, representatives of the German Telefunken Company have reported much better receiving conditions around Rio Janeiro, and the newspapers have lately announced that the Radio Corporation of America is contemplating a station at this point.

In England plans have been made for bringing the various parts of the British Empire into radio connection. Unlike the plans for communication over vast distances by means of huge stations, the Imperial committee, headed by Sir Henry Norman,

[3] Before the close of the war the U. S. Navy had designed an enormous station with a radiating antenna system in which the antenna could be used singly or in parallel, and which was to have been erected in the south. The coming of peace prevented the carrying out of this plan.

has recommended that stations of only moderate power be used, spaced at distances of not more than 2000 nautical miles, the intermediate stations acting as relays for the more distant. The first station of the Imperial chain, Leafield, near Oxford, was opened last summer and is expected to communicate with a station about to be built near Cairo. From Cairo the Imperial chain divides, one line extending to South Africa with an intermediate station in East Africa, while the other is expected to reach Australia by way of India and Singapore. According to the original recommendations, the stations of the Imperial chain

FIG. 7.



British Imperial scheme of 1919 for radio communication.

were to be equipped with electron tube generators, but apparently the British Post Office does not feel that the tube generators have been developed to the point where this is advisable. Therefore the station at Leafield has been furnished with a 300-KW. arc giving a current of about 250 amperes in the antenna. At present the masts at Leafield are only 300 feet high, having been installed there by the Marconi Company before the war. Later it is expected that these will be replaced by 600 or 800 feet masts. There have been heated discussions in England regarding the relative merits of the high-power, long-distance transmission systems in comparison with the moderate power, intermediate relay systems. There can be no doubt that the system of intermediate stations will give by far the most reliable communication, largely on account of the smaller variability of signal intensity at shorter

distances. And probably for Government purposes where reliability is of more importance than volume of traffic carried, this system is superior.

The plans of France for extremely long distance communication are centered around the huge transmitting station now being completed at Sainte Assise, between Fontainbleau and Paris. This station is expected by its promoters to communicate with Saigon, Indo China, 5500 nautical miles, Buenos Aires, 5950 miles, and of course many nearer points. The antenna for the high-power service is of the double Marconi type, being constructed in two parts with independent down leads in the centre. It is supported on sixteen 250-m. towers in two rows, 400 m. apart. High-frequency current will be supplied by two 500-KW. Latour alternators which will be used separately on the two antennas or which, when required, can be placed in parallel with the two antennas used as one, thus supplying 1000 KW. which will probably give between 1000 and 2000 antenna amperes. In addition to the high-power station, there is a medium power station for communication with European points, having a single mast 250 m. high which supports four antennas, which can be used independently or as one unit. High-frequency current is supplied from four 25-KW. alternators. There is also a low-power tube generator station with a 100-m. mast for communication with London and other nearby points. The receiving station for Sainte Assise is at Villecresnes, where there are six two-story brick buildings, the second stories of which contain the receiving coil antennas while the other receiving apparatus is on the ground floor.

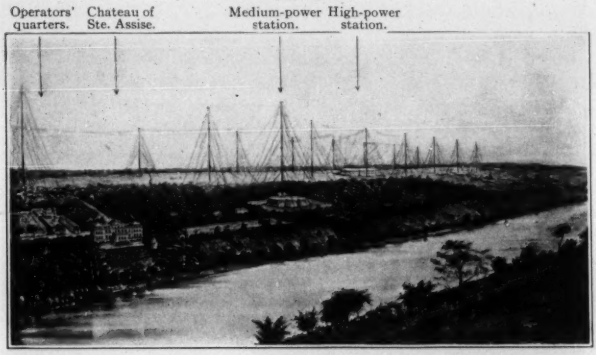
At present France possesses in the Lafayette station near Bordeaux the most powerful station in the world, though it will soon be surpassed by both Sainte Assise and Radio Central on Long Island. Lafayette is an arc station built near the close of the war by the American Navy. It has a Marconi type antenna supported by eight American Navy type self-supporting towers 250 m. high. High-frequency current is supplied by a 1000-KW. Federal arc giving a maximum current of 600 amperes at about 24,000 m. wave-length. This gives at present approximately twice as strong an electric field in America as any other European station.

The second most powerful station now in operation is the

German alternator station at Nauen, which is the veteran among high-power alternator stations, having been in continuous use since 1914. The antenna is supported by two 250-m. towers in the centre, with lower towers supporting the antenna ends. There are two 500-KW. generators, and the normal antenna current is 380 amperes. The receiving station associated with Nauen is at Geltow, near Potsdam.

Holland has under construction two stations for communication between the home country and Java, a distance of 6100 nautical miles, almost entirely over land. The home station, near

FIG. 8.



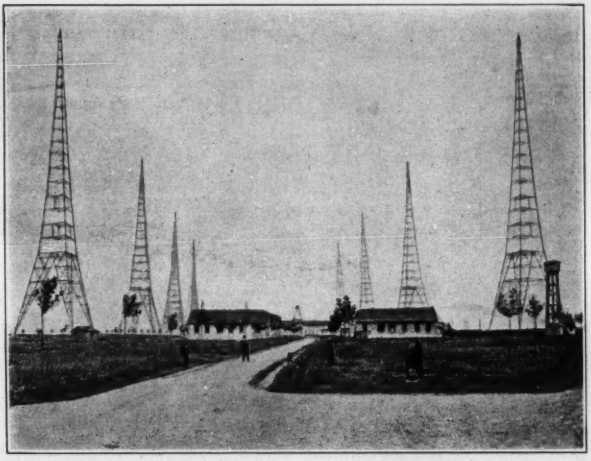
General view of the Ste. Assise station.

Amersfoort, is reported to be of the same power as Nauen. The Java station in the Malabar mountains is of interest on account of its novel antenna construction. The antenna is suspended between cables stretched across a gorge 3000 feet deep. One would not naturally expect that an antenna hemmed in between mountain walls would be very efficient, but it is claimed that experiments recently made have conclusively shown it to be entirely satisfactory. It was used in some interesting experiments during the war in the attempt to establish communication with Holland independent of the cables. In these experiments it was found that during a considerable portion of the time it was possible to send messages to Holland at night even with quite moderate powers, provided wave-lengths of 5000 or 6000 m.

were used. Of course such short waves would not be heard at all at this distance in the daytime.

Now as to the future of long-distance radio; it was stated in the beginning of the paper that the distances which can be covered in radiotelegraphy have always been limited by the receiving apparatus, and I see no reason to believe that this will not continue to be true in the future. At present there is a tendency to attempt to solve the problem of transmission by

FIG. 9.



View of Lafayette station near Bordeaux.

the use of enormous power, and it is possible that this can be done for covering distances of 3000 or even 4000 miles. But when one considers the power costs involved and the expense of erecting and caring for the enormous antenna structures which will be required, there is evidently a limit beyond which it is not profitable to go. This is the more evident when one remembers that doubling the antenna current, that is, quadrupling the power, can only double the telephone current in the receiving station, or in other words, only double the signal disturbance ratio which is

the real measure of communication,[4] so that any small receiving improvement which will double the strength of signal in comparison with the atmospheric disturbances accomplishes as much as quadrupling the power of the sending station.

The improvements in reception at San Francisco since 1920, already mentioned, have increased the signal disturbance ratio by at least twenty to thirty times, and have made possible the only present reliable transmission over distances greater than 4000 nautical miles. The sending station in this case, Cavite, is of moderate power, having only 200 amperes in the antenna, but has been made equivalent by the improved reception to a station of more than 5000 amperes received in the old way.

The question is often asked, will radio in the near future replace the cable for trans-oceanic communication?[5] Frankly, I do not believe that it will, and if it should do so, it will be because the atmospheric disturbances have been practically eliminated. But even now, there are certain classes of traffic which can be sent by radio much more economically and quite as satisfactorily where delays of a few hours are not objectionable. Continuous twenty-four-hour service is, of course, already possible where the distances are moderate. Here automatic high-speed reception is making radio a formidable rival of the wire and cable lines.

The best review of the present state of our knowledge of magnetism is the paper presented to the American Association for the Advancement of Science, Section B, in December, 1920. It is printed in *Science*, October 21, 1921, under the title, "Magnetic Susceptibilities," by S. R. Williams. G. F. S.

---

[4] Of course it is possible to strengthen a received signal by amplification to almost any extent, but unfortunately the atmospheric disturbances are also increased by the same amount, so that the only way to improve conditions is to increase the ratio of signal to disturbance, either by strengthening the signal or reducing the disturbances.

[5] In an article describing the improvements in reception from Europe during the great war, I made the statement that the use of unidirectional reception had reduced the number of hours during which a station like Nauen could not be received in America, from about 2000 hours in the year to approximately 100 hours. This unfortunately is no longer true, as the wonderful results obtained in 1918 were due to the enthusiastic, patriotic efforts of the boy operators, most of them amateurs, who strained their ears and attention to the breaking point to extract meaning from the jumble of signals and disturbances at Otter Cliffs. The less earnest peace-time operators cannot be expected to do as much.

In the January 12, 1922, issue of *Nature* there is an interesting discussion between two eminent chemists, one German, the other British, on the introduction of "Chemical Warfare." Sir T. E. Thorpe, in reviewing Lefebure's book "The Riddle of the Rhine," cited a passage, which, Geheimrat F. Haber claims, had "the intention to make the world believe that the materials for gas warfare were prepared by the German military authorities and chemical industry for the intended war and that experiments with this end were carried out in my institution (*i.e.*, Kaiser Wilhelm Institut, Berlin), if not previous to the war, at least from August, 1914, onwards." Such preparation Professor Haber denies categorically in these words: "Yet among all these men I have never met one who, previous to the war or during the first two months of its course, had conceived the idea of providing the field army with gas, or had made experiments or preparations for such a purpose. We had actually first to read in the French, Italian, and English press—as, for instance, in the *Pall Mall Gazette* of September 17, 1914—of the terrible things that were in preparation for us before we began to make similar preparations in view of the commencement of the war of position. . . . The question of gas as a means of warfare did not begin to engage our attention until the first three months of war had passed." The most significant statement of the German scientist is this made in discussing pre-war plans for gas warfare: "Perhaps there might have been some ground for suspicion if Germany could have foreseen the trench warfare, and if we could have imagined that the German troops could ever be held up for weeks and months before the enemy's wire entanglements." This frank avowal that Germany might have discarded her obligations to the Hague Convention before the outbreak of the war with the same conscienceless readiness with which she converted Prussia's guarantee of the neutrality of Belgium into the notorious "scrap of paper," this makes even more knotty the problem that many former residents in Germany are trying to solve, that is, how to reconcile the personal morality of the German citizen toward his fellows with his aggressive immorality in international relations.

In his reply Sir Edward Thorpe refers to this, that in 1887 the great organic chemist, Baeyer, in Munich, called attention in his lectures to the possible use in war of certain compounds causing temporary blindness. "The implication that the Allies were contemplating the use of poison gas as early as September, 1914, is so notoriously at variance with the truth that it scarcely needs serious refutation. If Geheimrat Haber could only have been present when Lord Kitchener made his dignified protest in the House of Lords, or have been a personal witness of the wave of indignation and disgust that swept over the country at the Germans' breach of the rules of war, he would not have penned his statement." "After all, the essential point is that it was used, and first used, by the Germans, and in flagrant contravention of a solemn promise given to the world."

G. F. S.

SURVEYING FROM THE AIR.*

BY

COLONEL E. LESTER JONES, A.M.

Director, U.S. Coast and Geodetic Survey; Commissioner, International Boundary—United States—Alaska and Canada.

ONE HUNDRED AND SIX years ago the United States Coast Survey, which later became the Coast and Geodetic Survey, began the task of charting the coastal areas of the United States. This task now includes all the outlying possessions since acquired, sections of which have not, as yet, been adequately surveyed. Portions of the coast, especially the Atlantic Coast, have been repeatedly surveyed, necessitated by the constant changes continually occurring. The action of waves, currents, tides, wind and man produces changes which render charts obsolete in a few years. It is in the accurate and detailed recording of these changed areas that aerial surveying will find its most useful application to the work of the Coast and Geodetic Survey.

The surveying done by the Bureau differs to a greater or less degree from surveying carried on by other organizations in this country, and this has necessitated the development of special methods and equipment to suit our particular needs. The standard methods and equipment of to-day are the result of successive improvements during the history of the Bureau, and to a large extent are due to the efforts of the personnel of the Bureau. Some methods and instruments have grown entirely within the Bureau, while others are adaptations of developments in other lines of scientific endeavor. A study is made of all inventions, discoveries and improvements that give promise of usefulness in surveying. Thus it was that the development of aerial photography was a subject of interest to members of the Coast and Geodetic Survey before the World War, an interest that was intensified by the rapid strides made in aeronautics during the war. As soon as possible following the Armistice arrangements were made with the Air Services of the Army and Navy to carry on coöperative experiments in aerial mapping, with the result that in June of

* Presented at a meeting of the Section of Physics and Chemistry of The Franklin Institute held Thursday, March 2, 1922.

1919 the Army Air Service photographed Atlantic City from the air, while during the following month the Navy Air Service experimented in the photography of underwater features in the vicinity of Key West, Florida.

In March of 1920, the Army Air Service photographed almost the whole outer coast line of the State of New Jersey for the Coast and Geodetic Survey. The Navy Air Service did some mapping of the Delta of the Mississippi River for the Coast and Geodetic Survey in March of 1921, and resumed operations there in the fall of the same year.

The various projects surveyed by the two Air Services have demonstrated the advantages of aerial photography for revision work for charts. There is one point especially in favor of this new method that should be stressed above all others, as it is the watchword of government organizations at the present time, and that is—economy. An aerial survey along the coast costs about one-third as much as a ground survey of the same region, and for this reason, if for no other, arrangements should be made for an extensive aerial mapping program.

We are planning to resurvey all of the changeable coast line of the Atlantic and the Gulf with the help of the Army and Navy Air Services, and the work will be done as rapidly as the funds and personnel available will permit.

The necessity for correct charts is obvious, and here is the chance to publish up-to-date charts at a small outlay for field work and, at the same time, furnish a peace-time vocation to the Air Services.

SURVEYING ACTIVITIES OF THE COAST AND GEODETIC SURVEY.

Before describing the experiments in aerial surveying in which the Coast and Geodetic Survey has taken part, it would be well to touch on some of the activities of the Survey, especially those with which aerial surveying is allied. Some of the ground methods now in use may eventually be replaced, either wholly or in part, by the aerial method, but at present practical aerial surveying is limited to only one phase of survey work, and that is the delineation of topographic features. The field of usefulness may be extended to other branches of surveying after much experimental work has been done, including improvement of instruments and perfection of methods.

Geodesy.—The basis of every extensive survey, and this includes aerial surveys, is a scheme of triangulation. The geodetic work of the Bureau includes among its operations three forms of triangulation, precise, primary, and secondary, the purpose of which is to furnish adequate control points for other surveys. A scheme of triangulation consists of a network of triangles, the vertices of which are known as triangulation stations, which are generally elevated above the surrounding country so as to be intervisible. These stations may be on hills, ridges, or mountain peaks, on lofty structures, as lighthouses or towers, or on level ground where special structures are erected to make the stations intervisible. The instrumental observations consist of the measurement of the angles of the triangles by means of a theodolite set up at the stations. The distances between stations are determined by computations.

Other geodetic operations bearing a close relation to triangulation are the astronomic observations for latitude and longitude, and the measurement of bases. The astronomic observations are made at stations where they can be tied in with the triangulation. Base measurement consists of the actual measurement along the ground of one side of a triangle in the scheme of triangulation. This measured line is used as a base for computing the sides of the triangles.

At present accurate aerial mapping requires numerous triangulation stations as control points where the area has not been previously surveyed. It is probable that aerial mapping may be so improved in the not distant future that fewer triangulation stations will be needed.

Topography.—The topographic surveying of the Coast and Geodetic Survey is limited to the areas bordering the coasts of the United States and its possessions. A topographic party, generally consisting of one engineer and four or five men, usually works as a sub-party attached to a vessel of the Survey, and it uses a launch or rowboat for transportation. The standard equipment is the plane table which has been in use many years and is well known. A large sheet of drawing paper is stretched over the board of the plane table, and on this sheet the engineer indicates in their true geographic position the shore line at high and low tide, marshes, woods, houses, villages, streets, wharves, bridges, railroads and any other features needed on the chart.

The topographic work along the Atlantic Coast at the present time consists only of revision of the older surveys. By ground methods this is almost as laborious a task as making a complete new survey, as often the changes are so numerous that the chart based on the old survey is hardly recognizable. It is in this revision work that aerial surveying has demonstrated its importance. A direct comparison between the photographs and the older survey can be made, and the changes that have occurred during the elapsed time can be easily discovered. In nearly every case there will be so many unchanged objects on the old map included in the photograph that the changes can be fitted into the old map without having to establish any control stations by ground surveys.

The aerial photograph contains much more data than the plane table sheet. The minute detail shown in the photographs can only be equalled by the topographer after a laborious and costly survey. Every bend shows in even the smallest streams. To one experienced in the interpretation of aerial photographs almost all the features ordinarily sketched in by the topographer can be recognized in the photographs.

It can be readily seen that the aerial photograph is especially valuable where there is a great amount of detail such as is found in a marshy area and in a village.

Along the coast of Florida there are many miles of coast line where the forest growth extends out into the water, and it is necessary for the topographer, using the old methods, to carry on most of his work while standing in two or three feet of water. Often the water is so deep that he cannot set up his instrument, and the work has to be done with a boat and sextant. This is a very unsatisfactory method and the aerial survey seems to be the logical one to be employed along coasts similar to this.

Many of the bays of the South Atlantic and Gulf coasts are bordered by marshy land, quite often too soft to hold a plane table with the requisite rigidity. These marshy areas are usually covered with a network of small streams that twist and wind their way through the soft soil. The accurate survey of these numerous streams by ground methods is a slow and costly process.

Hydrography.—Hydrographic surveying, or the delineation of under-water features with the lead line, has always been a more or less uncertain process, a groping in the dark. Sounding is car-

ried on from boats varying in size from a rowboat to the largest surveying vessel, the size used depending upon local conditions. A whaleboat or small launch is used for work close to shore, or in shallow bays, while large launches or vessels are used in the exposed areas. Soundings with the lead are taken at intervals of 100 feet or less in harbors, while in less important or deeper waters the interval is greater. Location of the soundings is determined by means of sextant observations from the boat made on signals on shore. A record of every observation and sounding is made and the soundings are plotted on a large sheet of paper in their correct positions.

An inspection of a hydrographic sheet gives one the impression that additional surroundings are hardly necessary, that the territory is well covered, but even the most detailed surveys are insufficient in some localities. Dangerous pinnacle rocks have been missed by the sounding lead.

To eliminate the uncertainties of the lead line survey the wire drag was perfected. A wire towed by launches sweeps through the water at a specified depth, say 80 feet. Any obstruction projecting above the 80-foot depth will catch and hold the wire, and can then be located and examined closely. The drag gives very certain results, as all objects projecting above the level of the wire can be charted.

The possibilities of aerial photography as an aid in charting under-water features was investigated by the Coast and Geodetic Survey in 1919 in coöperation with the Air Service of the Navy Department, with the hope that some of the usual hydrographic work could be eliminated. It had long been known that under-water features were visible from high altitudes, especially along the southern coasts, and the possibility of photographing the ocean bottom gave promise of material assistance in hydrographic surveying. The results of the experiments made in surveying the water from a plane will be described later.

HISTORICAL NOTES ON MAPPING FROM THE AIR.

Colonel Laussedat, a French army officer, suggested the use of aerial photographs for mapping purposes as early as 1845, in connection with his general investigations on photographic surveying. Those subsequently taking part in the development of ground photographic surveying also touched lightly on the aerial

phase, but very little advance was made until the beginning of the twentieth century.

Theodor Scheimflug, an Austrian, at the time of his death in 1911, was engaged in very promising researches along the line of aerial mapping. He had perfected a multiple camera for aerial use and a transformer for the correction of negatives for obliquity. The camera was designed for use in a balloon or kite, and consisted of a central camera pointing vertically down and seven other cameras arranged about the one in the centre and pointing obliquely in directions radiating from the centre. The seven oblique photographs, after rectification in the transformer, were combined with the central photograph to produce a composite photograph of an area whose diameter was five times as great as the altitude from which the photographs were made. This camera cannot be used to advantage in an airplane, and as the airplane is superior for mapping purposes to the balloon or dirigible, the instrument is very little used at the present time. The principles involved in the design of the 8-chambered camera and the transformer have been of great assistance in the development of aerial mapping and of equipment for use in the airplane and in the laboratory. Although aerial photography was limited to kites, balloons and dirigibles before the war, the experiments proved of value in demonstrating some of the difficulties that might be expected in photography from airplanes.

The world war demonstrated the importance of airplanes and aerial photography as war-time adjuncts, and also brought into prominence their peace-time possibilities. Aerial cameras were designed in great numbers in an attempt to find an efficient one. Each nation contributed a variety of models and tried them out at the front. The designers knew that an aerial camera must necessarily be of different construction from that of a camera for ground use. It should be simple in operation and automatic if possible. It should be substantial in construction so as not to be affected by vibrations. It should not be affected by low temperatures, or low atmospheric pressures, and should be capable of producing good results under conditions generally considered to be adverse for the ordinary camera. In the United States the K-1 type camera and the Bagley camera were designed. These are the two types being used almost exclusively in mapping for our federal agencies, and they appear to be superior to any other camera so far

tried in this country. Improvements have been made in these cameras from time to time.

The problem of the stabilization of the camera received attention in the countries interested in war mapping. Various devices were tried out, but none was entirely successful. The gyroscope received a great deal of attention, and its use was believed to be the solution of the problem, but no one has brought forth a satisfactory gyroscopic stabilizer. Level bubbles on the camera were used with some degree of satisfaction during the war, and at present are the only means used in this country to ascertain the verticality of the camera.

It may be well to note here that any statement made in this paper as to the superiority of any particular appliance or method refers to those known to the Coast and Geodetic Survey. With so many governments and commercial firms experimenting in aerial mapping, all attempting to advance, improvements may have been made recently which have escaped our notice.

As aerial cameras needed better lenses than the ordinary cameras, so also was the need made evident for improvements in plate emulsions and in filters. Experiments along this line have continued since the war, and now plates and films are especially treated for aerial use. The developing of roll films 75 feet and more in length has received some attention, several different models of development machines being now in preparation for the market.

A number of European countries have experimented in aerial surveying. The British are particularly interested, the large unsurveyed territories in India and Canada being the objective. Several surveys have been made in each of those countries.

In the United States the two Air Services have made aerial surveys for their own use, and for the use of the Geological Survey, Corps of Engineers, Hydrographic Office, Forest Service, Bureau of Soils and the Coast and Geodetic Survey. A few commercial firms have done some mapping, but most of their mapping is on a small scale.

Some interesting mosaics have been constructed at various times. A very good mosaic is the one of Rochester, New York, made by the Eastman Kodak Company and the Army Air Service.

To many persons a photograph is more intelligible than a map,

and consequently there may be created a demand for mosaics that will result in quantity production.

The term mosaic, as commonly used by aerial photographers, refers to a composite photograph made by joining several different photographs together. If the photographic work has been well done, and the terrain is fairly level, the mosaic will probably be very accurate, adjoining photographs overlapping perfectly or with very little discrepancy. Even in mountainous terrain a mosaic may be constructed by juggling photographs, which will appear correct owing to good joining, but it will probably be very inaccurate as to scale and direction, and cannot be substituted for a map.

Experiments are being conducted in this and other countries in the application of the aerial photograph to surveying rugged areas. We cannot predict what degree of success will be obtained.

AERIAL MAPPING PROBLEMS.

A study of the reports of the various organizations in all countries engaged in experiments in aerial mapping indicates that the majority have met the same problems and have the same difficulties to overcome.

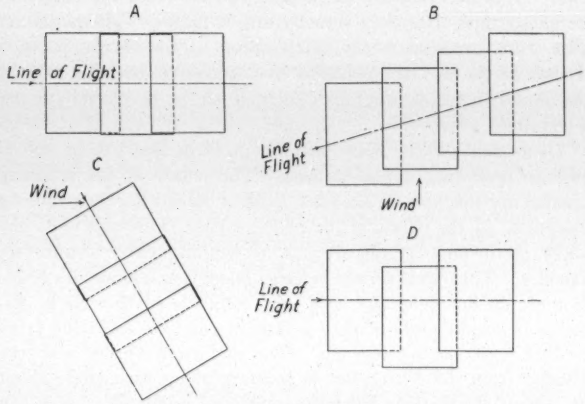
Personnel.—The human equation is an important one in any mapping flight, so that instruments are being perfected to lessen the work of the aviators. There are few proficient mapping pilots. To maintain an airplane at a constant altitude and to keep it on a desired course over a designated territory without too much banking and turning is a task requiring the greatest skill and much experience. It is necessary to fly at a constant altitude in order that all the photographs will be on the same scale. This is especially necessary when mosaics are to be constructed. Flying at a constant altitude and on straight courses reduces the number of tilted photographs and reduces the office work.

The accompanying diagram (Fig. 1) illustrates some of the difficulties encountered in mapping from the air which must be overcome by the skill of the flyers. In figure A, there is no cross wind and the photographs overlap each other in a satisfactory manner. In figure B the effect of "crabbing" is shown. The wind is normal to the course of the plane, resulting in the plane drifting, the successive photographs covering areas as shown. In figure C the observer has rotated the camera to compensate for the drift, so that with a cross wind the pilot heads his plane into

the wind enough to overcome the drift, with the result that the photographs overlap as in figure A.

In figure D are shown the results of lateral tilt in one photograph. This illustrates how a superficial examination of the photographs composing a series will give an idea as to the stability of the camera in a flight, especially as regards lateral tilt and, to a

FIG. 1.



Problems for the aviator to overcome.

less extent, fore and aft tilt. A series of mapping photographs joined together should follow a straight line and have equal overlap. If any photographs are displaced from the proper position, it is an indication of tilt.

The observer's duties are being simplified by the perfection of improved cameras and will be much easier as soon as a satisfactory stabilizer can be used.

In most aerial mapping projects, an attempt is made to have the camera pointing vertically down whenever a photograph is made. If the camera is tilted from the vertical the result will be that the scale of the photograph will vary. The only method used at present for maintaining verticality is level bubbles on the camera. The observer notes the position of the bubbles just before a photograph is made and, if necessary, adjusts the camera

to the vertical position. The accuracy of the level bubble method depends upon air conditions and the ability of the aviator to maintain a steady speed and a straight course.

Limitation.—All the aerial surveying for the Coast and Geodetic Survey is at present limited to flat terrain. This is due to the additional problems involved in the office work when the photographing is done over a territory where there is much relief. Elevated objects will appear farther from the centre of the photograph than they actually are in nature. The necessary office work involved in the computation of the correct position of each of the elevated points is now excessive, but this may be overcome if some stereographic method can be developed for use in terrain of great relief.

Distortion.—Lens distortion is a problem that can be solved only by providing a perfect lens. The lenses in the mapping cameras are not now as accurate as they should be, thus causing distortions of the edges of the photographs. For each lens, distances on the photographs are accurate within a circle of a certain diameter. This circle should be large enough to include the whole photograph, but generally it is not. Outside of this circle distortion is usually quite marked and occurs on lines radiating from the centre of the photograph. The distortion varies with the distance from the centre, but is constant along each circle about the centre. If the lens has been tested and rated, allowances can be made for lens error in the compilation of results.

Although a roll film will shrink while undergoing development, the general tendency seems to be for a change to occur along lines radiating from the centre, so that the effect produced is just a slight change of scale constant throughout the film. European nations prefer glass plates to films, probably because of the non-shrinkage of plates. The advantages of films over plates, especially as regards convenience and light weight, seem to outweigh the slight errors apt to occur due to unequal shrinkage.

Distortion of photographic paper is a grave source of error as it is variable, depending on the grade of paper, the method of drying and the atmospheric conditions after drying. A thin paper is very easily distorted, so for mapping purposes a double weight paper is recommended. The handling of the paper while developing and drying is important, as any stress applied while it is wet results

in stretching the paper. Distortion is also due to the method used in the manufacture of the paper.

It can be seen that the accumulative errors due to tilt, lens inaccuracies, and film and paper distortion might combine to produce excessive distortion in one photograph, while they might almost balance each other in the next. With reasonable precautions having been taken to minimize the possibilities of error, the results are not as inaccurate as might be expected.

Interpretation of Photographs.—The proper interpretation of aerial photographs is a study in itself. An oblique view is comprehensible at a glance, but a mapping photograph is a puzzle to the average person until it has been studied. The viewpoint is so unusual that the photograph does not appear natural. Even to the initiated, there are some features that are unintelligible. This is no more aptly illustrated than in photographs of tidal flats along the coast. To know what sections are above or under is a puzzle that can only be solved by a visit to the field and inspection on the ground or by means of an oblique photograph. Oblique photographs are of inestimable value in the interpretation of mapping photographs. Doubtful detail is cleared up in a wonderful manner. But there are some conditions that are not definitely shown even in the oblique views. Marshy land is an instance. Rushes growing in water appear as dry land in the photographs. This is just one illustration of the necessity for a field inspection in order to verify the interpretation of the photographic detail.

A stereoscopic study of the photographs is of great assistance in interpreting detail. Several types of stereoscopes have been perfected for special use with aerial photographs, and a new type is under construction now at the Bureau of Standards for the Coast and Geodetic Survey. In the meantime a Pillin stereoscope, a French instrument, is being used for studying aerial photographs.

ATLANTIC CITY PROJECT.

The first airplane mapping experiment in which the Coast and Geodetic Survey took part was the photographing of Atlantic City, New Jersey, in June and July, 1919, for the purpose of testing the possibilities of aerial photography in the revision of the topography of the coast line. The locality was well suited for the tests as the terrain is flat, and is well sprinkled with prominent objects suitable for control points. The marshy areas in the

vicinity are characteristic of much of the Atlantic Coast region where revision work is needed.

Various types of planes and cameras were used and tested. A

FIG. 2.

K-1 camera used for the delta work.

complete aerial survey was made with an Army plane using an L type camera. This is a plate camera, using 4″ x 5″ plates. It was fixed rigidly in the plane, thus making it necessary that the

pilot exercise extreme care in controlling his plane in order to keep the camera level. Every tilt of his plane tilted the camera. An

FIG. 3.

K-1 camera used for the delta work.

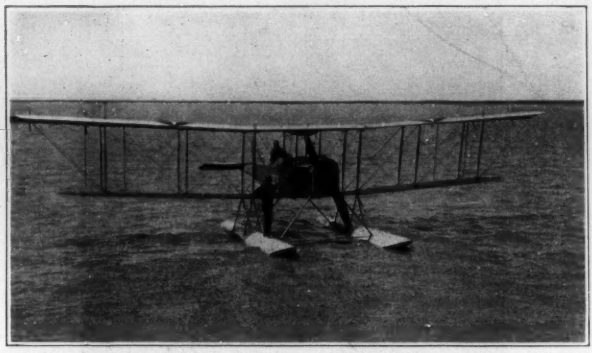
Army truck with photographic trailer made headquarters at Atlantic City, and was used for laboratory work.

Prints were made and assembled into temporary mosaic form in order to see if the terrain had been completely covered. It was

noted that the individual photographs did not join each other very well, but it was planned to rectify several of the photographs upon return to the home air station. This eventually proved to require too much laboratory work, and the compilation of results was very unsatisfactory.

Another Army plane using a K-1 camera spent three days at

FIG. 4.



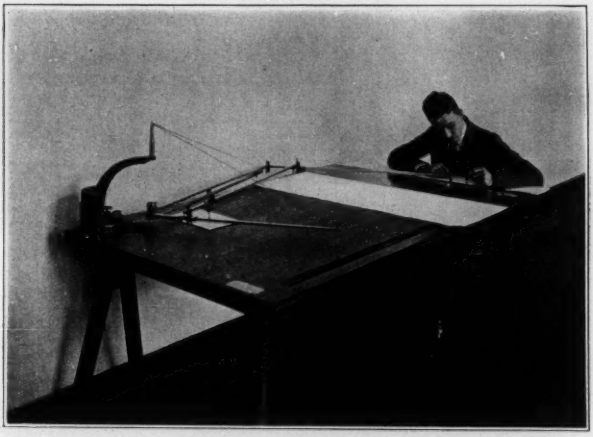
Seaplane used for the survey of the delta.

Atlantic City and completed the area designated, at an altitude of 7000 feet. The K-1 type camera is entirely automatic in action and uses a roll film 75 feet long, on which can be made 90 exposures each 18 x 24 centimetres in size. A focal plane shutter is used. Motive power is supplied by either an electric or wind-driven motor. Lenses of focal lengths of 10, 12, or 20 inches are used, set at universal focus. In fact all aerial cameras have their lenses fixed at universal focus. The light weight and ease of operation are two distinct advantages of this camera. The operation of the camera being entirely automatic, the photographer is free to attend to other necessary details of mapping. Photographs are made at intervals of from 15 to 30 seconds as desired, without any manipulation by the operator other than throwing a switch to start the camera working.

Personnel of the Army Air Service constructed a mosaic, using the photographs made with the K-1 camera, that proved to be

fairly accurate. There were some discrepancies, but they were to be expected. This mosaic was the subject of much study by members of the Coast and Geodetic Survey, and the conclusion was reached that aerial photography could be advantageously used for the correction or revision of our present charts. It was decided that, while a mosaic was interesting from the pictorial stand-

FIG. 5.



Pantograph used for reducing data from the mosaic to the scale of the chart.

point, the individual photographs were of greater value to the cartographer.

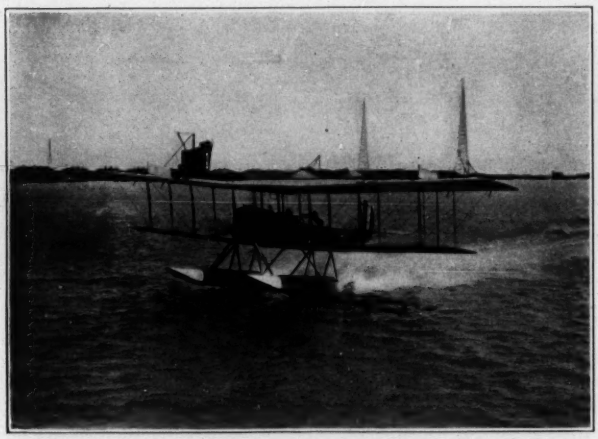
An attempt was made to map the locality from a naval plane, an L type camera being used at first, but a Bagley tri-lens camera was later used. The photographs made showed too much tilt. The Bagley camera was also used in a Navy dirigible with good results, the photographs being used to supply data in areas not covered by the K-1 camera.

The Bagley camera is a modification of the Scheimflug camera, but has only three lenses, as this number is better suited to airplane use. One lens photographs the terrain directly below while the other two lenses photograph the area on either side. The two side

photographs, being oblique, must be rectified in a transformer. After rectification, they can be joined to the central photograph forming a continuous strip covering a width approximately three times as great as the altitude from which the exposures were made. The camera is not automatic in its action.

A representative of the Coast and Geodetic Survey kept in

FIG. 6.



Seaplane used for the survey of the delta.

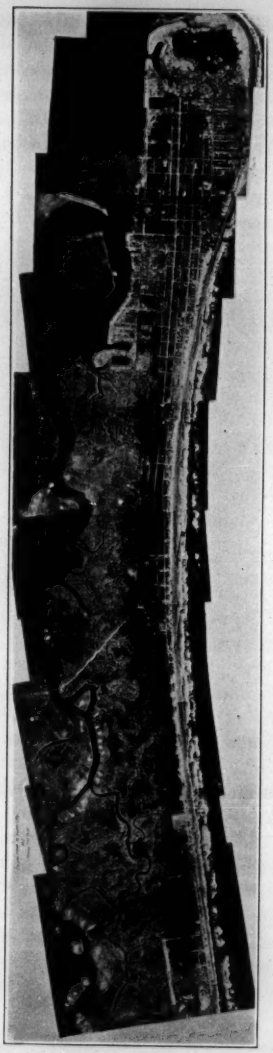
close touch with the photographic parties, and constructed some special signals for control points that would show in the photographs. These and many prominent objects, such as towers, spires, large stacks, standpipes, etc., that could be identified in the photographs, were located by triangulation.

The Atlantic City project, while demonstrating a possibility of immediate use of aerial photographs, also indicated that there were several problems yet to be solved, and that better methods might be used.

TOPOGRAPHIC REVISION OF THE COAST OF NEW JERSEY.

In March, 1920, the Army Air Service photographed 120 miles of the coast line of New Jersey for the Coast and Geodetic Survey.

FIG. 7.



Mosaic of the New Jersey coast from Corson Inlet to Ocean City.

A single flight was made from Cape May along the coast to Sea Bright, overlapping photographs being taken of practically all of the outer coast line. A De Haviland type, two-seated, photographic plane was used, photographs being made at an altitude of 10,000 feet. A K-1 type camera was used, mounted in gimbals so that it could be kept level by the observer, who watched two level bubbles placed on the camera itself. The photography was done while the plane was en route from Norfolk to New York, and no special field preparation was necessary. The project proved to be a very economical one for that reason. In two hours, 185 overlapping photographs were made, covering the 120 miles of coast line. To survey this same area by the ordinary ground method would require several months' time by one surveying party.

The film was developed in trays, having been cut into lengths about eight feet long for convenience in handling. Developing machines are now used, which lessen the work of handling these 75-foot lengths of film.

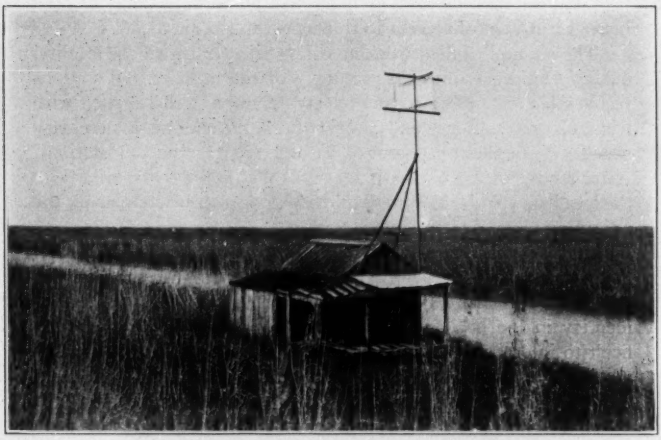
Two prints of each film were made for the use of the Coast and Geodetic Survey. One set was used for the construction of strip mosaics, the other set as individual photographs for the study of details or for examination under the stereoscope. Each print has a serial number to avoid confusion in handling.

Strip mosaics were constructed approximately four feet in length. This is a convenient size for handling in the drafting room, and also is the maximum length desirable for use with the pantograph. The mosaics were built up as follows: The end photograph was first glued into position on a mount sufficiently large to hold the complete mosaic, and the adjoining photograph was then trimmed on a line bisecting the overlapping area and fastened to the mount where it joins the first photograph. This process was continued with each photograph in turn until the mosaic was completed. The mosaics varied in length, as determined by the location of the control points, as it was necessary that each of the end photographs should contain a control point. Upon completion of the mosaic, the control points used in previous surveys were identified on the photographs if possible. This was a simple proposition when prominent objects were used, such as lighthouses, spires, etc. After identification of the control points, the distance was measured between each pair of points. The relation between the scaled distances and the actual distances on the

ground was the scale of the mosaic. The reason for measuring all the distances was for the purpose of checking the mosaic to see if it was accurately constructed.

After the mosaic had been tested for accuracy and its scale determined, the pantograph was used to reduce the data to the scale of the chart, which was 1:80,000. The pantograph was

FIG. 8.



A control point for the Mississippi Delta photographs. The ordinary triangulation signal does not show in a photograph from the air, but the small shed will show clearly.

reset for each mosaic, as the scale varied slightly between adjoining mosaics. The photographic mosaic pictured topographical features in great detail, but the draftsman selected only the data that are to appear on the chart, such as the shore-line at high tide and at low tide, streets, roads, lighthouses, prominent buildings, wharfs, etc. Some of the features were indefinite, and these were marked for verification in the field. The draftsman made as complete a map as possible, as he knew that this would lessen the work in the field later.

It would be well to mention here the distinct steps necessary in the completion of an aerial survey. They are: First, the photo-

graphic work; second, compilation of as complete a map as possible; third, a field inspection of the photographs, and the field work of establishing suitable control points; fourth, the final, accurate compilation of the data to be charted.

After compiling as much data as possible from the photographs in the office, arrangements were made for the field work. A special holder was made for the strip mosaics to facilitate work on them in the field. It is advisable to examine the mosaics in the field, but not necessary. The individual photographs may be used instead if it is inconvenient to transport the mosaics.

The amount of field work necessary will vary with the locality, quality of the photographs, accuracy of the mosaics, old stations recoverable, etc. The coast of New Jersey is well supplied with triangulation stations, and almost the only field work necessary was to check up the photographs and recover the old stations. After recovering an old station, even if it is in the centre of a field, the locality could be identified in the photograph by comparing the adjoining terrain with the photograph.

Only a few minutes were required to verify doubtful data on the photographs at any particular locality. It was generally a question of interpretation as some terrain was very difficult to identify in the photographs. Tidal flats in particular were difficult to interpret and had to be examined in the field. Generally all that was necessary was to interpret some particular shade in the photograph and its limits could then be easily discerned.

If the previous triangulation stations had disappeared or were of insufficient number, then the field work would have been increased considerably. Additional triangulation would have been necessary. But this triangulation would have been necessary in the same region if a topographic survey had been made from the ground, so this does not represent cost peculiar to aerial surveys.

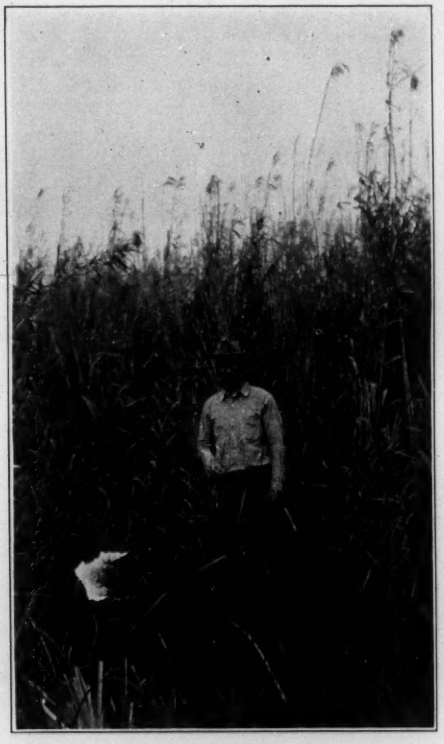
After the field inspection, the final office reduction was made. This necessitated slight corrections to the preliminary reductions. An estimated cost of the revision of the New Jersey charts by the old methods results in figures that total three times as much as the cost by the aerial method.

MISSISSIPPI RIVER DELTA.

A definite program was planned by the Coast and Geodetic Survey, following the New Jersey work, for the resurvey of the

Mississippi Delta. Early in 1921 arrangements were made for the aerial survey of the Delta by the Naval Air Service, with the

FIG. 9.



Wild cane.

Engineer Corps of the Army and the Coast and Geodetic Survey coöperating.

The Mississippi River Delta has grown out into the Gulf of Mexico from year to year, constantly fed by the sediment carried

down by the river from its upper reaches. The area is low, flat, and marshy, covered almost wholly by a dense growth of cane which attains a height of twelve feet or more. The numerous bayous and passes that thread their way through the marsh are usually lined with willows growing close to the water's edge. While the willows impart a picturesqueness to the streams they also tend to add to the difficulty of the surveyor by interfering with his line of sight. This is not the only factor that hampers the surveyor. The soft condition of the soil and the thickly growing cane render travel by foot a very difficult and laborious process. Previous surveys were made from scaffolds built above the cane and from boats. Practically all travel was by boat, as this is the quickest way to go from one station to the next throughout most of the Delta. Even from the scaffolds some details were hidden from view. Many lakes were missed entirely, as they could not be seen in the sea of cane or were hidden by the willows. The aerial survey discovered scores of lakes unknown before. The advantages of the aerial method over the ground method in this type of terrain are very evident even to the casual observer.

The lower end of the Delta extends approximately 40 miles into the Gulf with an average width of 15 miles, or a total of about 600 square miles. A large portion of this area was photographed in the spring of 1921. Early in November arrangements were made to complete the work, but owing to an accident to the plane the work was not taken up until December.

The Engineer Corps of the Army was anxious for an aerial survey, as it was believed that the photographs would prove of material assistance in coping with some of the engineering problems peculiar to this region. The photographs did bring out several interesting points and have proven very valuable to the engineer. A proper study of the Delta changes necessitates frequent surveys of some sections, and the aerial method is the cheapest and best in that case. The engineer who is interested in physiographic changes finds an aerial survey of immense value. Occasionally features are shown that are missed by a person walking over the ground. Slight variations in color, of vegetation or soil, can be plainly seen in the photographs although often indistinguishable by a person on the ground. This slight variation may be the key to the knowledge of a condition that at one time existed. This has been no more aply illustrated than in the case

where an ancient city in Mesopotamia, of an estimated population of four million, was surveyed from the air. What appeared to be

FIG. 10.

Air view in vicinity of Annapolis, Maryland.

meaningless mounds or blotches of color on the ground took on a definite form in the photographs, and it proved a comparatively

easy task to distinguish the various details such as outlines of streets, public buildings and houses of various sizes and shapes.

There was no expectation of finding ancient cities on the Delta, but what was more important, old stream beds could be traced. The changes due to overflowing of the banks in some places could be seen. The form of a new sub-delta at a recent break in the bank could be studied. In many different ways was the value of the survey to the engineer demonstrated.

The Coast and Geodetic Survey was primarily interested in producing as correct a chart as possible of the Delta. To this end, a representative of the Survey carried on the necessary triangulation for the control of the photographs, keeping in close touch with the aviators and the Army Engineers so as to supply their needs in regard to control points. The Naval Air Service furnished all the equipment and personnel necessary for the photographic work.

A seaplane equipped with twin floats was found to be the best type of aircraft to use for a photographic survey of the Delta or a similar region. Landing was restricted to bodies of water, which necessitated the use of a seaplane. The boat type of seaplane can be used for mapping, but it requires cutting an opening in the bottom of the boat. A close-fitting water-tight cover must be provided for this opening for use when the plane is in the water, while in a seaplane equipped with twin floats a sliding door to keep out spray is all that is necessary over the camera opening.

The plane used for the work on the Delta was originally designed as a torpedo plane, but was modified for photographic purposes. The pilot's seat ordinarily is in the front cockpit and the observer's in the rear, but this arrangement was reversed for two reasons: First, the extra weight of camera and equipment would be nearer the centre of gravity in the front cockpit; second, the pilot could observe the ground below him better from the rear cockpit, as the lower wing is not in his way. This latter advantage has since been offset by placing a negative lens in the bottom of the plane, through which the pilot can see the terrain immediately below.

A K-1 camera was used for this work. During the first flights the camera was mounted rigidly in the plane, but later was mounted in gimbals. A circular opening was made in the bottom of the fuselage just below the camera through which the photographs

were made. A sliding door over this opening was operated from the observer's seat, and it protected the camera from spray when taking off or landing.

Owing to the fact that the axes of the camera were fixed in relation to the plane, it was necessary for the aviator to exercise great care in operating the plane in order to approximate a stabilized camera. The ordinary level vials used on all planes, and installed on the instrument board in front of the pilot were the only indicators of the verticality of the camera. It is evident from the results of the work that in the hands of a clever pilot exceptionally good results can be obtained in this manner, but still this cannot be compared in effectiveness to a gimbal mount.

The lack of an up-to-date chart proved a handicap to the aviator. Although the main river and the important passages have been recently surveyed from the ground, some of the unimportant areas have not been surveyed for fifty years. Many changes have occurred in that time, in some areas very markedly. The only map available for the aviator to use as a guide was the chart as issued by the Coast and Geodetic Survey. Some sections had changed completely, so the chart was of very little value to him except along the shore-line of the main channels. It was almost impossible to plot courses for flights. He depended on his memory as to the area covered by each flight. He was quite successful in this in spite of the fact that it was his first extensive mapping project.

Weather conditions interfered much with aerial photography. During the latter part of March, all of April, and the early part of May, during which time the work on the Delta was in progress, only 16 days of a total of 47 were suitable for photographic mapping owing to cloudy and hazy weather. Five of the 16 were Sundays, and on three other good days the plane was out of commission due to the necessity for repairs. Therefore, there were only eight available photographic days in the 47.

The Engineer Corps, with the idea in mind of obtaining sufficient detail, requested that the photographs for them be made at an altitude of 5000 feet. The Coast and Geodetic Survey asked for photographs at a higher altitude, as this generally produces better results. Eight thousand feet was decided on as the altitude for the photographs covering the areas not included in the 5000-foot set. The Engineers were interested in the South and Southwest

Passes and the new sub-delta formed in Bird Island Sound. These areas were the first to be completed.

An interesting comparison can be made as to the area covered at the two altitudes. Nine hours' flying was required for the 5000-foot project covering 57 square miles, while nine and one-half hours at the higher altitude resulted in photographs of 175 square miles. In other words, about three times the area was photographed at 8000 feet as was covered in about the same time at 5000 feet.

All the flights were not made in the same direction. The direction of the wind governed the course for the day, and the locality chosen for photographing was that best suited for the particular courses. A pass was usually selected as a guide for the first flight, and the other flights were made parallel.

After completing the preliminary photographic work in the spring of the year, the prints were used by each of the bureaus according to its individual needs. Mention will only be made here of the work of the Coast and Geodetic Survey.

With the idea in mind of compiling as correct a chart as possible within a short interval of time, the necessary office work was started as soon as the prints were received. A revised chart was constructed for the use of the aviator in continuing his work, and was accurate enough for the use for which it was intended.

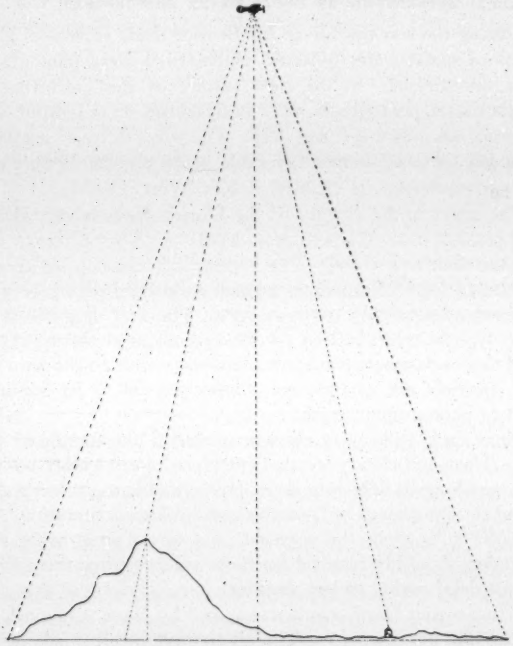
Mosaics were constructed of as large a size as could be conveniently handled. The scale of the mosaic was determined as accurately as possible by measuring between points of the photographs, the geographic positions of which were known. Knowing the scale, the mosaic was reduced photographically to the scale of 1 : 80,000, which is the scale of the chart at present issued. A tracing was then made of all the topographic features in the reduced photograph and the data transferred to the chart. Usually there were enough control points, or unchanged features, so that the tracing could be fitted in its exact position on the chart and the changes noted and transferred to the chart.

It was necessary to construct 13 different mosaics in order to include all the photographs. The results obtained were very good, considering the rapid manner in which the mosaics were constructed. They varied slightly in scale, but adjustments were made to compensate for this.

In addition to the preliminary revision, an index chart was also

made. This index chart is not only convenient for filing with the collection of photographs, but also is a practical subject for study by aviators interested in mapping from the air. It visualizes some of the difficulties attendant on a photographic project in territory

FIG. 11.



Horizontal displacement due to relief.

where there are no regular features to serve as guides in flight. The effect of "crabbing" is clearly shown. The relative areas covered by the photographs at 5000 feet and at 8000 feet are here shown in a way that demonstrates one of the advantages of the higher altitudes.

A complete up-to-date chart of the Delta has never been issued. Surveys extending over a period of years have been combined, but

owing to rapid changes continually occurring, the earlier surveys would require corrections by the time the last one was completed. A complete aerial survey, which required only eight or ten days' flying, will give a correct chart of the Delta as a whole for the first time.

EXPERIMENTS IN UNDER-WATER PHOTOGPAPHY.

During the war the Naval Air Service made successful photographs of under-water objects. Submarines were photographed below the surface. In the clear waters of the California and Florida coasts, photographs were made of the ocean bottom where the water was only a few feet deep. The possibilities of usefulness for survey purposes seemed favorable, so arrangements were made for experiments in the vicinity of Key West, Florida.

The water in the vicinity of the Florida Keys is very clear, it being possible to see the bottom in depths of 50 or 60 feet or more from the deck of a vessel. The bottom is broken up by irregular growths of coral. Sometimes a small coral head only 4 or 5 feet in diameter rises almost to the surface. The wire drag is essential in this type of ocean bottom for locating all coral shoals. It was hoped that aerial photography would replace some of the wire-drag work, possibly all, as the clear waters seemed to be admirably suited to photographic work.

The experiments were carried on during the month of July, 1919. Haze and cloudy weather interfered considerably with the work, resulting in only four days' photographic work being done. During certain seasons unfavorable meteorological conditions seem to be the rule along the seacoast, and any photographic work undertaken should be planned for those seasons when there will be the least delay owing to bad weather.

A two-seated Naval seaplane, manned by Navy personnel, was used for the photography. The photographs were made at altitudes varying from 500 feet up to 4000 feet. Some photographs were made pointing vertically down, others at small angles with the vertical, and still others, made with the hand-held camera, were at the usual angle for taking obliques. An L type camera was used at first, but some trouble developed with the mechanism, so a Navy type hand-held camera and an ordinary Graflex were used for the remainder of the work. Various types of filters and plate emulsions were tried under the different light conditions.

In order to approximately orient the photographs, it was necessary to know the geographic location of at least two points on each photograph. As the area photographed was several miles from the nearest islands, it was necessary to have two boats in each picture. Two survey boats travelled on parallel courses about 400 yards apart, and on each boat sextant observations were made to determine the exact position at frequent intervals. In this way the position of each boat could be determined at any particular instant, and as the photographer in the plane recorded the time each photograph was made the photographs could be oriented from the position of the two boats shown in them. As the boats travelled at 8 miles an hour, and the plane at 55, it was necessary for the plane to fly forth and back, exposing a plate every time it passed over the boats.

While photographs were made of the bottom through 30 or 40 feet of water, it was demonstrated that aerial photography was not a practical method to use, as the results were too uncertain. It is possible that, with further development of photographic methods and equipment, more positive results will be obtained. It would be a natural supposition to expect that shoal areas would show in sharp contrast to the surrounding deeper area, as the light rays travelled through different amounts of water. It was also expected that a shoal, being of different color than the ocean bed in the immediate vicinity, would be plainly indicated. The results obtained were very confusing. Level bottom appeared as being dotted with shoals, which upon investigation proved to be due to vegetation growing on the bottom or else to vari-colored bottom. Shoals, whose locations and depths were known from hydrographic surveys, could not be found in the photographs. The condition of the surface of the water seemed to affect the visibility of the under-water features, as did also light conditions. In fact, the limiting conditions necessary for good photographs, with the uncertain results, proved to be too strong an argument against aerial photo-hydrography. There seems to be a limited field of usefulness in the photography of possible channels in sedimentary rivers, or in shoal water bays, but even this will eliminate very little field work. We must continue to take soundings and do wire-drag work.

CONCLUSION.

Aerial surveying has proven its worth. Speed, economy and multiplicity of detail are strong arguments in its favor. Relieving the surveyor of disheartening labor in territory verging on the inaccessible, but now limited to flat terrain, it is probable that it will soon be developed to the stage where it can be used in mountainous territory with further lessening of the hardships incidental to mapping. There are thousands of square miles of level terrain where aerial photography can be advantageously used at the present day.

The Coast and Geodetic Survey has no desire to enter the field of aviation, as no doubt the two Air Services should be able to furnish all the photographs needed, at the same time keeping their personnel in training. Lack of appropriations has hindered those services so far, but it is hoped that the future will bring better conditions.

The Coast and Geodetic Survey has the chart compilers, some of whom were trained in interpretation of aerial photographs during the war, while others have studied the subject since that time. If the Air Services will furnish the photographs, the necessary office work and the supplemental ground surveying will be done by the Coast and Geodetic Survey, and the charting of our coasts will be expedited.

The Relative Affinity of Some Gas Molecules for Electrons. L. B. LOEB. (*Phil. Mag.*, January, 1922.)—"In some gases the electron must on the average make a number of impacts n with the molecules of the gas before it can strike one in such a manner as to attach to it to form the negative ion." The present paper has for its purpose the determination of this quantity, n, for some gases. The way to the result is not an easy one. It is hedged with exponential formulas and menaced with uncertainties, yet this rather astounding conclusion comes forth—"In spite of the difficulties in determining its value accurately, the constant of electron attachment, n, is, even in its order of magnitude, a marked and characteristic property of the different kind of gas molecules." For N_2 and H_2 it comes out infinite, which means that these molecules never annex an errant electron. For CO it is 160,000,000 and for Cl_2 it is 2100 or less.

The suggestion is thrown out "that n is dependent on either the electrons striking a particular point in the atom, or in its striking a molecule in some particular state of physical or chemical activity."

G. F. S.

CHANGE OF THE PHYSICAL PROPERTIES OF MATERIALS WITH PRESSURE.*

BY

ERSKINE D. WILLIAMSON, B.Sc., M.A.

Physical Chemist, Geophysical Laboratory, Carnegie Institution, Washington, D.C.

In the Geophysical Laboratory our sphere of inquiry includes all questions relating to the chemistry and physics of the processes occurring in the earth's crust. Since pressure is a factor which cannot be neglected in considering reactions which occur at any great depth beneath the surface, our attention has been directed for some time toward devising ways and means of carrying out exact experimentation under the greatest possible range of pressure, as well as of temperature, which may be compassed conveniently in laboratory practice. In most cases our final aim has been chemical rather than physical, but a number of points have been touched which are interesting to students of exact science in general. The object of the present paper is to collect certain results of this nature obtained by ourselves or others showing the general effects of high pressure on the more fundamental physical properties.

At the outset special mention must be made of the series of papers published in the last fifteen years by Dr. P. W. Bridgman. These furnish a veritable mine of information on the subject in hand and have already led to many valuable results. Individual papers will be continually referred to throughout this review.

For the sake of the reader who is not familiar with the technic of modern high-pressure work the range of experiment will be roughly indicated. With the materials which are convenient for use at present, exact measurements at ordinary temperatures are rarely made at pressures exceeding about 12,000 atmospheres or 200,000 pounds per square inch. For special reasons a few results have been obtained at pressures considerably higher, but the wear and tear on the apparatus offsets the advantage gained by the greater range. At higher temperatures practical difficulties prevent the use of more than a moderate pressure. At the

* Presented at a meeting of the Section of Physics and Chemistry of The Franklin Institute held Thursday, December 15, 1921.

highest temperature at which we have experimented, about 1300° C., a pressure of 1200 atmospheres has been used—that is, about one-tenth of the maximum at room temperature.

The difficulties of making exact measurements of any physical quantity whatever under the conditions outlined are very considerable and much time is consumed merely in devising tools for the enterprise. The glass test-tube of the ordinary chemical laboratory must be replaced by stout-walled steel vessels, generally called bombs, tightly sealed, so that most of our observations have to be indirect. Measurements of some electrical quantity or of the motion of a piston are practically the only feasible ones, except at lower pressures, where optical methods may be used if the bomb be fitted with small windows. Such windows are really just small cylinders of glass held in place by some form of packing similar to those used for holding the electric connections. Dr. W. Wahl [1] has used these devices up to pressures of 4000 atmospheres in some chemical work.

A diagram of one of the bombs used in the determination of the simpler quantities is shown in Fig. 1. It is essentially a steel test-tube with thick walls. The only measurements made, when experiments are performed with this bomb, are of pressure and piston displacement so that it is used for the determination of the changed volume of the contents of the bomb under pressure. The change of volume is measured directly by means of the motion of the piston and the pressure is measured on a secondary gauge which will be described later. The exactness of the volume measurement is dependent on having an absolutely leak-proof packing for the end of the piston. Such packings have been most ingeniously developed by Bridgman.[2] The details of one type are shown in Fig. 2. The most necessary feature is that the external pressure holding in the packing acts through washers which have a smaller area than that on which the internal pressure acts, so that the pressure per square inch on the washers is greater than the pressure inside the bomb. Well-made packings of this nature are completely leak-tight.

A primary desideratum for pressure work is, naturally, a convenient means of measuring the pressure set up in the bomb. It is not generally sufficient to measure the pressure on such a

[1] W. Wahl: *Phil. Trans.*, Series A, 212, 117.

[2] *Proc. Am. Acad. Arts. Sci.*, **49**, 627, 1914.

piston as that in the bomb illustrated since the friction between the packing washers and the bomb may amount to several hundred atmospheres, as shown by the difference in external pressure while the piston is ascending or descending. At low pressures a procedure frequently used is to balance the pressure by means of

FIG. 1.

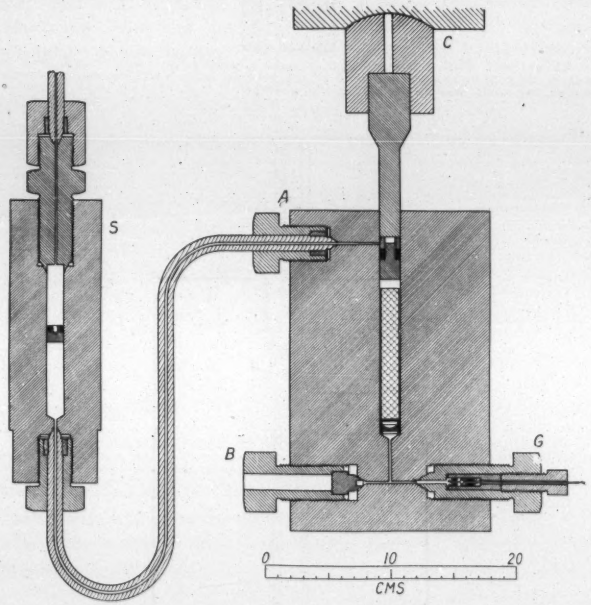
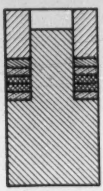


Diagram of bomb and connections to scale as shown. The specimen to be experimented on is placed in the hole in the thick-walled steel cylinder and surrounded with kerosene. The plunger is forced downward by means of a hydraulic press and the pressure thereby produced is measured by means of the resistance gauge *G*. When the plunger is near the top of its stroke an initial pressure may be applied by pumping liquid through the extra container *S* and the by-pass *A* by means of an ordinary compression pump. The motion of the plunger is measured by a dial gauge not shown in this diagram.

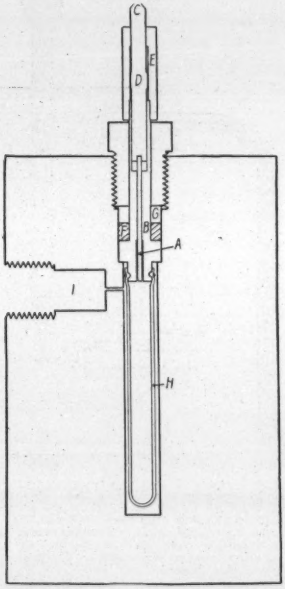
a mercury column, but this is available only up to a few atmospheres. The most general type of absolute gauge is that in which the pressure is weighed on a small movable piston of known cross-section. Fig. 3 illustrates a suitable design. In using such a method there is of necessity a slow but continuous leak round

FIG. 2.



(Actual size). Packing regularly used to make movable piston pressure tight. Over the stem of the plug beginning at the top is a hardened steel collar, a soft steel washer, a copper washer, two rubber washers and another copper washer.

FIG. 3.



Absolute gauge as used by Bridgman (*Proc. Am. Acad. Arts Sci.*, 44, 205, 1909). *A*, piston; *B*, cylinder; *C*, hardened steel point on which the equilibrating weights are hung; *H*, easily collapsible rubber tube containing a viscous liquid. The pressure vessel is connected at *I*.

the moving piston, so that it is not in all cases a convenient scheme to adopt. Such an absolute gauge is still a necessity, however, for the calibration of convenient secondary gauges for use in

the bulk of the experimental work. A secondary gauge consists of an instrument for measuring some fundamental property, the change of which with pressure has been previously determined, using the primary gauge as pressure indicator. The property usually chosen is the electrical conductivity of a small coil of wire. Fig. 4 illustrates the arrangement used in the Geophysical Laboratory and Fig. 5 shows the coil in place in the bomb. For measuring pressures up to 100 atmospheres an ingenious secondary gauge has been used quite recently at Johns Hopkins

FIG. 4.

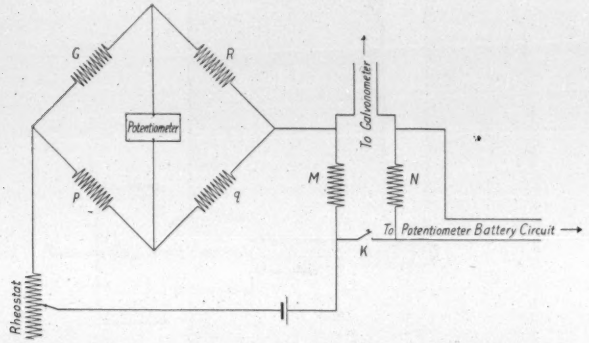


Diagram of bridge connections used for measuring changes of resistance of therlo pressure gauge. A variation in the resistance of the gauge coil G gives rise to an e.m.f. which is read by the potentiometer. Constancy of current ratio is obtained by equalizing (1) the drop in potential across M, a coil in series with the bridge, and (2) the drop in the coil N which is in the potentiometer battery circuit.

University. It consists merely of a water interferometer [3] in which the water in one of the optical paths is subjected to the pressure in the system.

It is now becoming possible to calibrate a secondary gauge by means of fixed points much as a thermometer is calibrated. This will no doubt be the general method in the future. To make this a reasonable procedure it is necessary to determine with the greatest possible accuracy a sufficient number of transition points under pressure to act as the fixed points in a rôle exactly analogous to that of the melting points of pure substances as used in high temperature work. Bridgman [4] has determined a number of

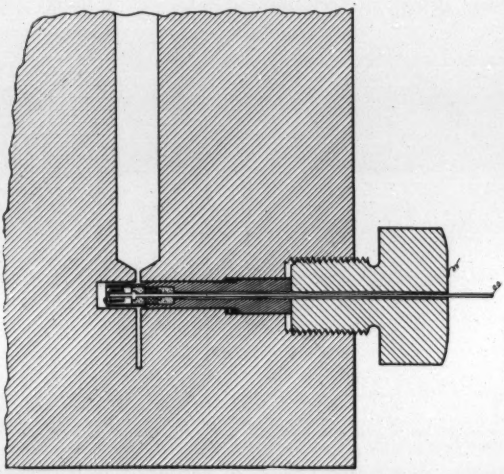
[3] Von Doren, Parker, and Lotz: *J. Am. Chem. Soc.*, **43**, 2497, 1921.

[4] *Phys. Rev.*, **3**, 126, 1914; **6**, 1, 1915.

such points, but these should be independently verified, all precautions being taken as regards chemical purity so that the most suitable and most accurately defined points may be chosen. The freezing pressures of water [5] and of mercury [6] give two excellent points at fairly high pressures.

The change of electrical resistance with pressure will be taken as the first example of the action of pressure on a physical property. Since metals are the commonest conductors they will be treated first.

FIG. 5.



Section through lower half of bomb showing details of our most recent pressure gauge.

Alloys which have a very low temperature coefficient of change of resistance are most easily experimented upon as the system of temperature control need not be so perfect. The alloys known as manganin and therlo have been specially investigated, as they have been used for the making of the secondary gauges already mentioned. Both have low temperature coefficients, while therlo has the advantage of its low thermo-electromotive force against

[5] P. W. Bridgman: *Proc. Amer. Acad. Arts Sci.*, **47**, 517, 1912.
[6] P. W. Bridgman: *Proc. Amer. Acad. Arts Sci.*, **47**, 417, 1911.

copper. The change of resistance for these alloys under pressure is very small—of the order of two parts per million per atmosphere—and is positive, that is, the resistance increases with the pressure. In the case of manganin the change is linear, but in the case of therlo the resistance increases more rapidly for the first few hundred atmospheres when the relation becomes practically linear for at least 10,000 atmospheres. Table I shows a typical calibration table of one of our therlo gauges.

The resistance of pure metals in general decreases with the pressure. Bridgman [7] showed some years ago that antimony

TABLE I.

Calibration of Gauge.

Pressure megabars	Electro-motive force microvolts
0	0
1,000	1,141
2,000	2,291
3,000	3,448
4,000	4,609
5,000	5,769
6,000	6,928
7,000	8,085
8,000	9,241
9,000	10,396
10,000	11,549
11,000	12,701
12,000	13,851
13,000	15,000
14,000	16,148

and bismuth are exceptions, and more recently [8] lithium, calcium, and strontium have been added to the list. Great care must be taken with the temperature control in experiments on pure metals since the coefficients are usually such that a difference of 0.001° C. makes about as much difference as a pressure of one atmosphere. The rate of change of resistance is a rather small quantity, being measured in parts per million per atmosphere, and as the pressure increases this rate becomes still smaller. Table II contains a number of results from the papers already referred to. I am not

[7] *Proc. Am. Acad. Arts Sci.*, **52**, 573, 1917.

[8] P. W. Bridgman: *Proc. Am. Acad. Arts Sci.*, **56**, 61, 1921.

aware of any practical use that has been made of this property except that already mentioned of making secondary pressure gauges. It may be, however, that such a method of obtaining reproducibly very small changes of resistance will find future uses. On the theoretical side we are led to test the various theories of electrical conduction to see if they can give a satisfactory

TABLE II.

Changes of Resistance of Metals with Pressure.

Metal	Ratio of resistance at 12000 kg. per sq. cm. to resistance at 1 kg. per sq. cm.
Lithium	1.0927
Sodium	0.5854
Potassium *	0.2748
Magnesium	0.9510
Calcium	1.1550
Strontium	1.8160
Tungsten	0.9838
Mercury (liquid)*	0.7377
Bismuth	1.2672
Tin	0.8895
Cadmium	0.8927
Lead	0.8546
Zinc	0.9436
Aluminum	0.9542
Silver	0.9600
Antimony	1.1464
Copper	0.9780
Nickel	0.9823
Cobalt	0.9895
Iron	0.9729
Platinum	0.9776

*The temperature during experiment was 0°C. except in the case of mercury and potassium in which it was 25°C.

account of the changes observed. These considerations have led to a very much modified theory.[9] The underlying idea is that electrons can move freely in the interiors of atoms but have difficulty in jumping from atom to atom. Conduction is thus mainly a function of the average distance apart of the atoms and the amplitude of the atomic vibrations. The classical expression

[9] P. W. Bridgman: *Phys. Rev.*, **9**, 269, 1917, and **17**, 161, 1921; especially the latter.

for the resistance will still hold under the newer theory, namely,

$$R = \frac{2\,mv}{e^2 nl}$$

where e is the charge on an electron, m the mass of an electron, n the number, l the mean free path and v the velocity of the electrons. The difference lies in the fact that the mean free path has a much larger value than in the classic theory, being bounded now not by collisions, but by gaps between atoms.

Metals which have only one electron in the outer shell of their atomic structure are the best conductors as they give the largest value of n. If a good conductor like copper is contaminated with an even better conductor like silver or gold the conductivity is cut down not because of any great difference in n, but because the atoms do not fit so well in the general structure so that gaps are increased and l is correspondingly diminished.

Quantitatively considered the theory yields the known results such as Ohm's law and the general law for pure metals that the temperature coefficient of electric resistance is inversely proportional to the absolute temperature. Qualitatively it can be shown that the less well-known pressure effects are at least not in conflict with it, which statement is not true as regards any of the older theories. It was, of course, these pressure effects which led to the formulation of the theory, and if that was the only result obtained from high-pressure work it would of itself be sufficient to justify all that has been done in this field. It is not the part of this communication to discuss the matter at greater length. Those who wish further information will find it in the papers already quoted.

Measurements have been made of the effect of pressure on another fundamental electrical quality, namely, the thermo-electromotive force [10] at a junction of two metals, and from these results the effect on the value of the Peltier and Thomson heats can be calculated. It was hoped that this study would cast a considerable amount of light on questions as to the nature of electrical phenomena in metals. In general one may say, however, that the results from this point of view were negative. It can be shown that none of the simple theories proposed, such as the free gas electron one, is at all competent to explain the observed facts.

[10] P. W. Bridgman: *Proc. Am. Acad. Arts Sci.*, 53, 269, 1918.

Bridgman says: "The unexpected complications found makes these results disappointingly meagre in their suggestions as to the nature of the thermo-electric mechanism. The conclusions are mostly negative in character. The most unmistakable inferences may be drawn as to the untenability of the old gas-free electron theory of metals, but this is not now new enough to be worth the experimental trouble. This conclusion was drawn ten years ago by Wagner from his data up to 300 kg. and the results of this paper can add nothing to the conclusions of

TABLE III.

Electrical Resistance of Solutions.

Temperature, 25° C.; Salt, NaCl.
Concentration, 0.292 Per Cent.

Pressure megabars	$R_x/R_{x=1}$
1	1.0000
497	0.96636
997	.94552
1522	.93410
1869	.93100
2127	.93048
2404	.93158
2680	.93416
3470	.94826
4161	.96796
3101	.94028
1967	.93006
1	.99984

Wagner in this regard, since our results are in essential agreement over our common range. Further than this, the results suggest most strongly that the thermo-electric mechanism must be comparatively complicated, that it cannot be at all of the simplicity imagined by the free electron theory and that most likely the effects which we measure are the resultant of different effects which, sometimes at least, work in opposite directions!" The later views on conductivity already mentioned may lead to a much better theory of the Thomson and Peltier effects and there are at least no contradictions.

The electrical conductivity of solutions has been a subject of

much study. Cohen and Schut [11] have collected the older results. In dealing with this subject we find factors which do not enter into the question of conductivity in solids, but on the other hand, the matter is in some ways less complicated. The effects of pressure on such conductivity may be grouped under the following heads:

(1) By the compression of the solution the number of ions per unit volume will be increased.

(2) The degree of dissociation of the dissolved substance may change. It may decrease or increase, but is subject to thermodynamic laws. The governing factor is the change of volume involved.

(3) The degree of hydration of the ions may change. This is subject to the same laws that operate in condition (2).

(4) The internal ionic friction changes, being probably connected with the viscosity.

(5) The small part of the current carried by the solvent may also be changed for reasons similar to the above.

For very dilute aqueous solutions in which the salt is completely dissociated one might expect offhand that the conductivity would change in exactly the same ratio for different salts, at least when allowance has been made for the slight differences of compressibility. This is found, however, *not* to be the case. We are thus driven at once to the conclusion that the changes in the internal ionic friction and the viscosity of the solvent water do not run parallel, but the former must depend in some way on the solute. The atomic weight may be one of the deciding factors. For example, if we make equally dilute solutions of the chlorides, bromides, and iodides of sodium and potassium, and draw curves [12] showing the per cent. change of resistance with pressure, the curve for a sodium salt will always lie above that of the similar potassium salt while considering salts of the same metals the curves will lie in the order—chloride, bromide, iodide—the last lying above the others.

In the Geophysical Laboratory we are attempting to make more accurate measurements than have so far been made, over a more extended pressure range, but qualitatively our results resemble the older ones. One of the features of our apparatus

[11] Cohen and Schut: *Piezochemie. Akad. Verlag.*, Leipzig, 1919.

[12] Cohen and Schut: *Op. cit.*, p. 309.

is the use of a very small cell current which is made possible by the use of an amplifier [13] in the galvanometer circuit. This is, so far as we know, the first application of such an amplifier to this kind of work. The use of a small current is of great assistance in minimizing temperature disturbances.

The curves in Fig. 6 show the nature of the results [14] obtained. For dilute solutions the resistance at first decreases and then, after reaching a minimum value, begins to rise rather rapidly. For

TABLE IV.

Electrical Resistance of Solutions.

Temperature, 30° C.; Salt, NaCl.
Concentration, 20.259 Per Cent.

Pressure megabars	$R_x/R_{x=1}$
1	1.0000
250	0.99922
495	0.99968
759	1.0011
1035	1.0038
1522	1.0112
2059	1.0227
2470	1.0334
3102	1.0534
3525	1.0689
3980	1.0869
2845	1.0449
1845	1.0174
881	1.0017

strong solutions, on the other hand, the resistance increases at once. There is an intermediate solution where the initial effects just balance and the resistance does not change for the first small amount of pressure. The middle curve of the three almost meets this requirement. Table IV shows how nearly this is true—the resistance varies only one-tenth of one per cent. in the first seven hundred megabars.

The main effect observed in all cases seems to be a change of internal friction which in dilute solutions decreases to start with and then at higher pressures increases rapidly.

[13] R. E. Hall and L. H. Adams: *J. Am. Chem. Soc.*, **41**, 1515, 1919.

[14] From some experiments by Dr. R. E. Hall—as yet unpublished.

Leaving the discussion of electrical properties and turning to the field of elasticity, we find that the cubic compressibility is the most natural first subject for study. It is well known that for "perfect" gases the isothermal compressibility is inversely proportional to the pressure, but as regards other substances the average person's knowledge is in many cases limited to the old school dictum that "liquids are incompressible." In reality, of course, no substance is completely incompressible, and if one is

TABLE V.

Electrical Resistance of Solutions.

Temperature, 25° C.; Salt, NaCl.
Concentration, 23.983 Per Cent.

Pressure megabars	$R_x/R_{x=1}$
1	1.0000
265	1.0023
505	1.0055
768	1.0100
1020	1.0153
1258	1.0211
1529	1.0285
2106	1.0473
2557	1.0645
3155	1.0903
3533	1.1082
3912	1.1267
2663	1.0686
1725	1.0340
823	1.0105
378	1.0032

thinking of liquids not in comparison with gases but with solids, one is more apt to think of a liquid as a rather highly compressible substance.

The bomb already shown in the first diagram is excellently adapted for the required measurements. The photograph shows the apparatus as actually used. In general two sets of readings are taken, in one of which the substance which is being experimented on is placed in the bomb entirely surrounded by oil, while in the other a piece of steel of the same initial volume is substituted. The difference of piston displacement in the two cases gives directly the difference between the change of volume of the

substance and of the steel piece. The use of this bomb is described in various publications.[15]

The effect of pressure on the compressibility is to diminish it. That is, for any substance the change of pressure produces a diminishing change of volume. In the case of liquids this effect

TABLE VI.

Volume of Water as a Function of Temperature and Pressure.

Pressure kg. per sq.cm.	Volume 0°C.	20°C.	40°C.
0	1.0000	1.0016	1.0076
500	.9771	.9808	.9873
1,000	.9578	.9630	.9700
2,000	.9260	.9327	.9403
3,000	.9015	.9087	.9164
4,000	.8807	.8880	.8956
5,000	.8632	.8702	.8778
6,000	.8480	.8545	.8623
7,000	....	.8404	.8485
8,000	....	.8275	.8360
9,000[a]	....	.8160	.8249
10,000	....	....	.8149
11,000	....	....	.8056
12,000	....	....	.7966
12,500	....	....	.7922

is very noticeable as can be immediately seen from Tables VI and VII, which show some results for water and for kerosene. In the case of water at 40° C., for instance, as shown in Table VI, the first 500 kilos of pressure produces a change of volume of the water of 2 per cent., while the 500 kilos from 12,000 to 12,500 produces about 0.5 per cent. The same behavior may be noticed in the case of solids, except in the case of a few for which the change is so small that it cannot be detected with our present limits of accuracy. Richards [16] and his pupils, although only working at low pressures, have showed the effect for a number of the more compressible metals, while our results at the Geophysical Laboratory show it for almost all the substances experimented on.

[15] Adams, Johnston and Williamson: *J. Am. Chem. Soc.*, **41**, 12, 1919. Adams and Williamson: *J. Wash. Acad. Sci.*, **9**, 30, 1919. L. H. Adams: *J. Wash. Acad. Sci.*, **11**, 45, 1921.

[16] Richards: Various papers in *J. Am. Chem. Soc.*

The least compressible substance known is diamond. This had been predicted on the basis of the various approximate formulæ [17] linking the compressibility with other physical constants such as the melting point. Direct measurements made here verify the prediction. A hydrostatic pressure of one megabar decreases the volume of a diamond by barely two parts in ten million, so the highest pressure obtainable in the laboratory can only compress a diamond by a fraction of one per cent.

In Table VIII there are presented a number of our results. Some of these have been published in the papers already quoted, while others are results as yet unpublished. The result for diamond

TABLE VII.

Compressibility of Kerosene at 20° C.

Pressure megabars	Fractional change of volume between 2000 megabars and P, megabars
12,000	0.150
11,000	0.142
10,000	0.133
9,000	0.123
8,000	0.111
7,000	0.098
6,000	0.084
5,000	0.068
4,000	0.050
3,000	0.027
2,000	0.000

is a new one and is the mean of three results, the two more recent being determined by experiment on rather more favorable material than was available when L. H. Adams (*op. cit.*) published his preliminary value. The change in the compressibility is tabulated, except when the results were irregular owing to the material not being quite homogeneous so that no accurate estimate of the change could be made. In general the less compressible substances show less change of compressibility, but this is not without exception and in any case there is no approach to proportionality of the two quantities.

When more accurate measurements can be made we shall have a useful check on theories of atomic attraction. X-ray analysis has elucidated the arrangement of the atoms in many of the simple

[17] L. H. Adams: *Op. cit.*

crystals so that the compressibility, and more especially the change of that quantity with the small changes in the packing of the atoms brought about by the compression, will give some idea of the laws governing the forces of attraction or repulsion. Born and Landé have already made some use of the compressibility in this connection, but the check is not a competent one owing to the insufficient degree of accuracy of the experimental results.

TABLE VIII.

Compressibilities and Changes of Compressibility of Solids.

Material	Compressibility per megabar x 10^6	
	at 0 megabar	at 10,000 megabars
Diamond	0.18	0.18
Sodium chloride	4.12	3.53
SiO_2, glass	3.1	...
SiO_2, quartz	2.70	2.31
Bismuth	3.00	2.57
Cadmium	2.24	1.70
Lead	2.21	2.16
Tin	1.89	1.64
Zinc	1.74	1.43
$CaCO_3$, calcite	1.39	1.39
Aluminum	1.32	1.32
Silver	0.97	0.97
Copper	0.75	0.75
Gold	0.57	0.57
Marble *	1.41	1.41
Granite *	2.13	1.84
Basalt *	1.88	1.55
Diabase *	1.26	1.26
Plate glass *	2.27	2.05
Cast iron	0.89	0.76

*The first column gives the compressibility at 2000 megabars in these cases.

The change of compressibility has not been examined from this point of view so far as I know.

In the case of rocks there is a line of evidence about the value of the elastic properties under a far greater range of conditions than is possible in the laboratory. I refer to the use that may be made of observations of earthquake waves. As is well known, seismographic records are obtained at many stations all over the earth whenever an earthquake occurs, but the nature of these records and the deductions to be made therefrom are not so generally known. The characteristic tremors which reach a station

consist of three parts: (a) Vibrations similar in character to the sound waves in air; (b) transverse vibrations analogous to light waves; (c) waves which have traveled over the surface of the earth. The last of these three produces the main shock, but our present interest is only in the first two, which have passed through the earth roughly speaking along chords of a circle. The velocity of the wave fronts depends on the density of the material through which they are passing as well as on its compressibility and rigidity. By observing the time of arrival of the disturbances at stations at different distances from the centre of the earthquake activity, a series of observations is obtained from which the wave velocity at any depth may be calculated. The details of the computations involved are not of interest here, but it should be mentioned that only one assumption is involved—namely, that the velocity is simply a function of the depth or, in other words, that the velocity at a depth of a certain amount is the same at all latitudes and longitudes. It is evident that close to the surface this postulate is not justified, but since the velocity of the waves is several miles per second and as the surface layer includes only a small part of the path of a wave which has come through from a distant point, this does not invalidate the results obtained.

After having computed the velocities of the two waves at all depths we are provided with two relations connecting the density, compressibility, and rigidity of the material of the earth. Some idea of the distribution of density can be obtained from astronomical data, and if this distribution could be accurately obtained, it would be possible to calculate the elastic constants. Since at present the density distribution is not sufficiently well known, it is only possible to calculate the ratio of these constants. Table IX gives the values of the velocity of the compressional wave at various depths and also of what is known as "Poisson's ratio," [18] which can be obtained unequivocally. It is noteworthy that while the velocity changes enormously, the ratio of the elastic constants remains almost constant. To give some idea of the pressure range covered by these results from earthquakes, it may be mentioned that at a depth of only 50 km. the pressure is in the neighborhood of 15,000 kg. per sq. cm., which is

[18] This is defined as the ratio of the lateral stretching to the longitudinal compression under a direct thrust.

already rather beyond the range used in our laboratory compressibility measurements.

In concluding this part of the discussion, I should like to draw attention to one more deduction that can be drawn from earthquake data. It might be supposed that the material of the earth is all of the same nature as at the surface and that the increase of density towards the centre of the earth is due to

TABLE IX.

Velocity of Earthquake Waves and the Elastic Constants of Rocks.

Depth in km.	Velocity* km. per sec.	Velocity† km. per sec.	Poisson's† ratio
0	7.4	7.17	0.258
100	7.76	7.59	0.273
200	...	8.01	0.272
300	8.57	8.42	0.272
400	...	8.83	0.274
500	...	9.22	0.272
600	...	9.62	0.274
700	...	10.00	0.273
800	...	10.37	0.272
900	...	10.73	0.271
1000	11.24	11.07	0.270
1100	...	11.42	0.270
1200	...	11.75	0.269
1300	...	12.08	0.268
1400	12.06	12.40	...
1650	12.53	...	...
1900	12.80	...	...
2500	12.95	...	...

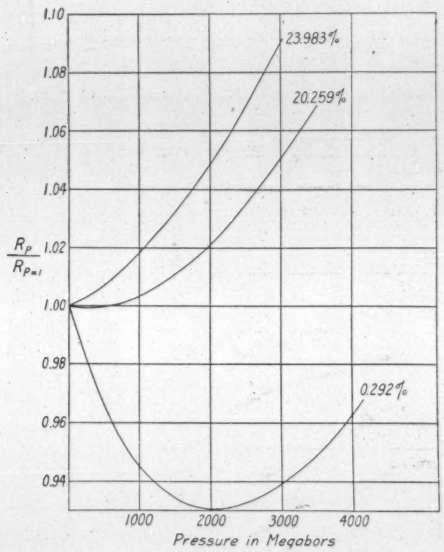
*Calculated by Adams and Williamson from earthquake data of the Dominion Observatory, Canada.

†Calculated at Göttingen by Wiechert and his co-workers from earthquake data.

compression. If this were so we should have another equation connecting the density with the surface density and the compressibility, so that we could now solve the previous problem completely. The actual details of the mathematics are rather burdensome, although no special difficulties are encountered, so I shall merely state here the general result obtained. The supposition mentioned can be proved quite untenable, as the calculated mean density of the earth proves to be much too low. Part of the increase of density is therefore due to the presence of heavier material, as has, of course, always been supposed by a large school of thinkers.

In the closing paragraphs a few words will be said about another fundamental property of liquids, the viscosity. Anyone who has worked at all with pressures knows that this is a property which is affected in the very highest degree by pressure. For instance, in using an ordinary oil pressure pump with a good grade of lubricating oil, almost immediate response to pumping

FIG. 6.

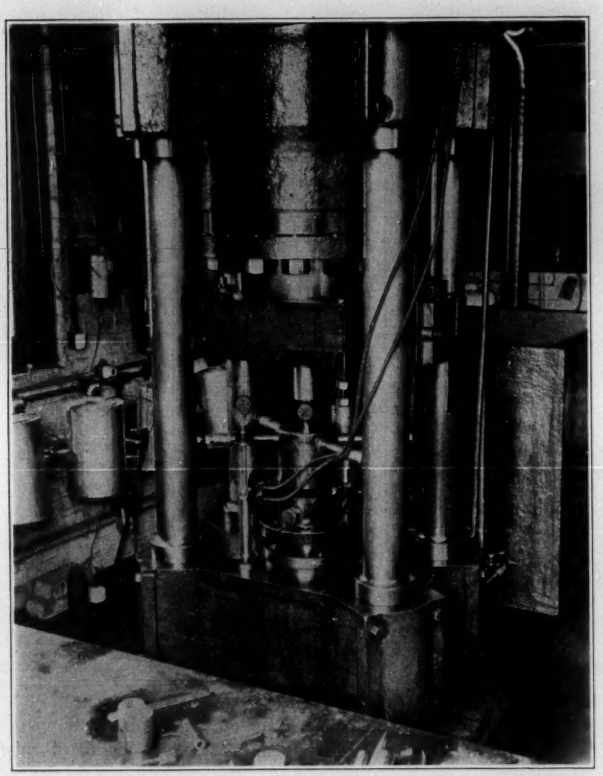


Curves showing the pressure effect on the electrical resistance of solutions. The data are collected in Tables IV, V and VI.

is made by a gauge at a distant part of the apparatus, but at about three or four thousand atmospheres at ordinary temperatures this is no longer so, if even a fairly short length of tube separates the gauge from the pump. Judging by our experiences of this nature, when measuring compressibilities with kerosone as the transmitting fluid, it would seem that at 12,000 atmospheres kerosene is more viscous than vaseline is at the same temperature and zero pressure.

In the case of lubricating oils this change of viscosity with pressure may be of some importance, and several researches have been carried on in regard to it. I quote from a paper by

FIG. 7.



Photograph of hydraulic press with the bomb and connections as used in compressibility work.

J. H. Hyde:[19] "The research here described was undertaken for the Committee on Lubricants and Lubrication of the Depart-

[19] *Proc. Roy. Soc. London*, **97**, 240, 1920.

ment of Scientific and Industrial Research, for the purpose of the analyses of the results of a previous investigation into the efficiency of power transmission through a worm-gear when different kinds of oil, animal, vegetable and mineral, were used as lubricants. Since pressures of the order of five tons per square inch between the lubricated surfaces of worm-gears are not uncommon, a knowledge of the rates of variation of the viscosities of the oils up to these pressures was essential, and as this information was not obtainable, the experiments necessary for the determinations were put in hand at the request of the committee."

TABLE X.

*Viscosities of Typical Oils Under Pressure.**

	K			
Pressure kg. per sq. cm.	Victory Red (mineral)	Trotter oil (animal)	Rape oil (vegetable)	Sperm oil (fish)
1	1.00	1.00	1.00	1.00
157.5	1.54	1.20	1.13	1.23
315	2.67	1.60	1.44	1.54
472.5	4.62	2.00	1.88	1.94
630	7.94	2.40	2.35	2.39
787.5	12.26	...	2.91	...
945	19.58	...	...	3.14
1102.5	...	3.54	3.50	...
1260	...	5.03	...	...

*Table by J. H. Hyde, *op. cit.*

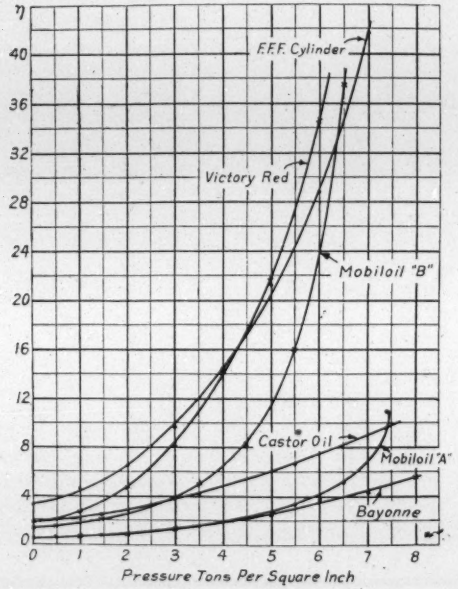
Table X and Fig. 8 show a number of the results obtained. K stands for the ratio of the viscosity under pressure to the viscosity at one atmosphere. The maximum value of K found for the range covered is 26.5 for Mobiloil BB under a pressure of 1019 kg. per sq. cm.

Returning now to our own experiences, these have led us to use a good light motor oil (such as Peerless motor spirit) for medium pressures, kerosene in our higher pressure bombs, and petroleum ether when a low temperature is combined with a high pressure. The use of these is possible only in a leak-tight apparatus. If it is necessary to have a small leak, as for instance in using an absolute gauge of the moving piston type, a viscous liquid must be used where the leak is. In a great deal of the older high-pressure work this difficulty greatly diminished the value of the

results, and all credit is due Doctor Bridgman for his pioneer work in the development of leak-proof apparatus.

In conclusion one may say that the work already done on these lines has borne good fruit, and as the initial experimental difficulties have been largely overcome it should be possible in the future to obtain more numerous and more accurate results with a corre-

FIG. 8.



Curves from J. H. Hyde (*op. cit.*) showing the effect of pressure on the viscosity of oils.

sponding increase in their usefulness. The late Professor Tait, in his well-known book on the "Properties of Matter," wrote while dealing with the subject of compressibility: "It is greatly to be desired that more, and more accurate, data should be obtained in this matter—though the problem is one of very great uncertainty as well as difficulty. Difficulty incites rather than repels a true experimenter, but uncertainty is paralyzing." In

the rather less than twenty years which have elapsed since Tait died these uncertainties have been removed, so that while the difficulty remains the paralysis has been permanently cured. With sufficient care and patience a degree of accuracy may be reached which is beyond what he dreamt of, while the range of experimentation has been increased tenfold.

GEOPHYSICAL LABORATORY,
CARNEGIE INSTITUTION OF WASHINGTON,
WASHINGTON, D. C.,
December, 1921.

On Whispering Gallery Phenomena. G. V. RAMAN and G. A. SUTHERLAND. (*Proc. Royal Society*, A 705.)—The interesting acoustical properties of such structures as the domes of St. Paul's Cathedral and of the Capitol at Washington have for a long time called for scientific explanation. The late Lord Rayleigh regarded the sound-wave as following the concave surface around from their source to the point where they were so distinctly audible. This was supported by using a directed source of sound placed near the curved surface. When this source sent its waves off tangentially to the surface the greatest effect was observed. Furthermore, when a bird-call as sound origin and a sensitive flame as recipient were employed, it was found that a rather small obstacle located near the curved wall shut off most of the effect. The authors experimented with a flexible mirror along which a ray of light took its course and they observed bands of light and darkness. With this optical analog as a guide, they carried out a series of experiments in the dome of St. Paul's. A steady source of sound was maintained at the wall at one point. Then observations were made by ear at various points around the circumference. As the ear was moved radially away from the wall, it was evident that at intervals about equal to the wave-length of the wave sound and comparative silence alternated. "Very pronounced fluctuations of intensity were also noticeable when the observer's head was moved circumferentially; that is, parallel to the wall, and this latter effect, though detectable everywhere, was most marked near the far end of the diameter of the gallery in which the source was situated." Both of the types of fluctuations were confirmed by the impartial sensitive flame. When a semicircular archway was used both the radial and the circumferential variations manifested themselves but with certain differences of character.

"Rayleigh's theory is attractive in its simplicity, but as is evident from the foregoing experimental results, it does not fully explain the observed phenomena." G. F. S.

The Growth and Decay of Photo-thermionic Currents from Oxide-coated Filaments. H. D. ARNOLD and H. E. IVES. (*Proc. Nat. Acad. Sciences*, Dec., 1921.)—Merritt and Case have shown that the illumination of the oxide-coated filament of an audion is followed by an increase of the current between the filament and the plate. Merritt further showed that the increase was chiefly due to radiation of short wave-length and interpreted the effect as due to an increased emission of electrons from the filament under the excitation of the incident light.

In the present investigation light that had passed through a red glass fell on the filament. The change in space current was recorded by a string galvanometer. It was concluded that the heating effect of the red light is mainly responsible for the changes occurring. When light transmitted by blue glass was used the heating effect was quite small, yet there was still a change in the space current. A study of this, as the heating current in the filament varied, led the authors to believe that some light effect different from the true photo-electric effect is the cause of the phenomenon. There is a similarity in the features of the growth and decay of the current to the variation of selenium in resistance under illumination that justifies the suggestion "that the cause of the light effect in the oxide-coated filament may be closely related to that which gives selenium its photo-sensitive properties."

G. F. S.

Some Problems of the Sea. L. F. FARIS. (*Jour. Washington Acad. Sciences*, March 4, 1922.)—"A problem of much importance in the study of the physics of the earth is the determination of the intensity of gravity at sea first, to furnish further information that will enable us to ascertain more accurately the shape of the earth, and second, to determine the distribution of the densities in the so-called 'isostatic shell' of the lithosphere.

"Researches in this and other countries have made it certain that the outer seventy miles of the earth's material is in a state of approximate isostatic equilibrium. If we assume a surface seventy miles below sea level under the continent and on this surface lay out squares approximately one hundred miles on a side and extend vertical planes from these to the surface of the earth, we should have the same mass in each of the columns, though some of the columns would be a mile or more longer than others. In other words, each column of equal cross-section is found to have about the same pressure on the nucleus at a depth of seventy miles below sea level as any other column. Do these conditions exist under the ocean? The answer to this question requires the obtaining of observations for the intensity of gravity over ocean areas."

G. F. S.

CONTROL OF CORROSION BY DEACTIVATION OF WATER.*

BY

FRANK N. SPELLER, B.A.Sc., Member A.S.M.E.

Metallurgical Engineer, National Tube Company.

INTRODUCTION.

REPLACEMENTS made necessary due to corrosion of iron and steel in this country have been estimated to run over one million tons per annum. While this is perhaps little better than a guess, it is probably not overstating the facts. Much of this loss occurs in piping, boilers and other closed systems. For example, a large modern building contains over two hundred miles of piping of all kinds. These are the arteries of the structure, which are both difficult and expensive to replace. The hot-water piping is most subject to attack, frequently lasting less than ten years under modern conditions.

One of the most fruitful means for effecting economy is through the elimination of waste. The subject of this paper deals particularly with the conservation of iron and steel in contact with water in closed systems, but it may be well to first outline briefly some of the important facts and principles relating to corrosion in general.

The Electrolytic Theory of Corrosion has been stated in various terms in a number of articles which may be referred to by those who are particularly interested in this phase of the subject.[1] The essential reactions are: The action of hydrogen ions in water which results in the solution of iron; the concentration of hydrogen ions, acidity of solution; the polarization of the metallic surface by deposition of hydrogen which protects the metal from further attack; the retarding effect of ferrous hydrate in solution; and the removal of deposited hydrogen and

* Communicated by the Author.

[1] "Corrosion of Steel," A. S. Cushman: J. OF FRANKLIN INST., **165**, 111, 1908. "Corrosion of Iron and Steel," W. H. Walker: *J. Am. Chem. Soc.*, **29**, 1251; **30**, 473, 1907. "Preservation of Hot Water Supply Pipe," Speller and Knowland: *Trans. A. S. of H. and V. Engineers*, vol. 24, 1918.

ferrous hydrate by oxygen in solution in water. Without the last reaction, corrosion cannot proceed to any appreciable extent, except in rare cases where a high hydrogen ion concentration is maintained, as where water contains magnesium chloride. In this case the water when heated brings about the following reaction: $MgCl_2 + 2H_2O = Mg(OH)_2 + 2HCl$. In contact with iron, ferrous chloride is then formed, which is hydrolyzed by water ($FeCl_2 + 2H_2O = Fe(OH)_2 + 2HCl$). These reactions are cyclic and will continue in the presence of free oxygen, which disturbs the equilibrium of the last reaction by formation of insoluble ferric hydrate ($4Fe(OH)_2 + O_2 + 2H_2O = 4Fe(OH)_3$).

In most cases the amount of free oxygen available determines the amount and character of corrosion. It is therefore convenient to divide corrosion of iron into three broad classes:

I. *Atmospheric corrosion,* where oxygen is available in large excess.

II. *Underwater corrosion,* where the amount of oxygen present is limited to the solubility of that gas in water.

III. *Soil corrosion,* in which the ratio of moisture to available oxygen varies considerably but where the influence of contact of the metal with dissimilar materials and different electrolytes is likely to be an important factor in accelerating corrosion. This has no reference to the influence of electrolysis from stray electric currents *per se,* which is another problem[2].

In this paper the author confines the discussion to the second of these three classes, which includes broadly, corrosion of the interior of pipes, tanks, economizers, boilers and other closed water systems which form such an important part of building, and power plant construction. Before discussing the practical solution of this problem, it may be well to refer briefly to the main factors which influence corrosion.

EXTERNAL FACTORS.

The main factors which control the rate and distribution of corrosion of iron in water (and this applies, generally speaking, to brass and some other metals) are given below in order of importance:

(a) Amount of oxygen in solution;

[2] Report of Committee on Electrolysis, 1921, *Am. Inst. of Electrical Engrs.*

(b) Temperature;
(c) Quantity and velocity of flow;
(d) Quality of water; presence of one or more electrolytes in solution;
(e) Contact with electro-negative material.

Irregular corrosion, known as pitting, is brought about by contact of the metal with electro-negative materials such as mill scale, brass, copper, but in the absence of free oxygen the influence of all other factors mentioned is insignificant, except where acid is generated continuously, in which case there will be some solution of iron but much less where free oxygen is not present.

COMPOSITION OF MATERIAL.

Before discussing what has been done and what may still be accomplished to conserve such material, it is in order perhaps to answer the question: What may be expected from special treatment of the metal, or what has been done towards the production of a non-corrosive metal suitable for such conditions? A large amount of thought and work has been devoted to this field by metallurgists with some results of note in the manufacture of special alloys such as monel metal, dur-iron, stellite, stainless steel (high-chrome steel), and other alloys, all of which, due to their non-rusting qualities, have useful fields. However, the use of these alloys is unfortunately limited by their high cost and the fact that such metals have not as yet been successfully fabricated for general purposes. So that we must still use such well-known material as zinc, tinplate, brass, copper, wrought iron and steel (uncoated or galvanized) and for most purposes for economic reasons, the choice is usually confined to the last two mentioned. Steel carrying 0.25 per cent. copper has proved much better than non-copper bearing steel under atmospheric corrosion, but unfortunately has shown no superiority underwater or underground.

RELATIVE RATE OF CORROSION.

In passing, it may be useful to refer to a few of the many comparative tests of wrought iron and steel in water lines which have been made in recent years, for opinions are still somewhat divided in certain quarters on this question.

The author has previously summarized some of the practical information from experience and tests in service on wrought iron

and steel pipe in a paper before the International Association for Testing Materials—1912. Since that time considerable data have been collected from various sources which are summarized in Table I. An extensive series of tests in acid mine water was reported on by Committee A5—A.S.T.M., 1921[3]. The conclusion reached is practically the same from all these investigations, *viz.*, that under water the origin and composition of iron makes comparatively little difference in the rate or character of corrosion. Whatever the influence of composition may be it is apparently small compared with the marked influence of variations in surface finish of the metal, internal strain, contact with other materials which are relatively more electro-negative in character, to say nothing of the predominating influence of other external factors referred to above which, after all, have most to do with controlling the rate of corrosion. Enough has been said to indicate that at present in many cases, we have no choice but to consider means for keeping the water from contact with the metal or to remove the corrosive power of water and thereby render it inactive. Thus corrosion may be prevented or greatly retarded either by means of protective coatings or by removing the free oxygen from water.

PROTECTIVE COATINGS.

Many protective coatings have been devised to protect pipes and other metallic structures under water. These may be divided into (a) non-metallic coatings such as paints and bituminous dips, (b) metallic coatings. The latter may be classified into metallic coatings which are electro-negative to iron and those which are electro-positive. The former include lead, tin, copper, nickel, and protect only so long as the coating is intact, after which the coating metal usually accelerates corrosion and results in pitting. Electro-positive metals include such as zinc, aluminum and certain kinds of brass. Iron is protected by such metals, even though the protective coating does not entirely cover the surface, until the area of iron exposed becomes so large as to extend outside the range of galvanic influence of the more electro-positive metal. Zinc coatings on account of their economy and ease of application are most generally used and find a wide and useful application in various forms such as hot galvanizing, electro-

[3] *Proc. A. S. T. M.*, vol. 21, p. 157, 1921.

galvanizing, Sherardizing and spraying. Each of these methods of zinc coating has special advantages for certain purposes which have been developed by experience.[4]

There is good evidence that iron and steel acquire under certain conditions a protective film or scale which often has considerable influence in warding off the attack of hydrogen ions in water. Iron or steel which contains over 0.10 per cent. copper has a very decided tendency to develop a strongly adhering and more or less impervious coating of rust *under atmospheric corrosion*, but under water this metal corrodes like non-copper bearing steel, evidently because the rust formed under these conditions does not adhere so well and is more open in its physical structure. Steam pipes which have been in use for many years often exhibit such coatings, particularly where the steam carries a small amount of oil, which results in a protective coating consisting of a mixture of hydroxides of iron and certain oily deposits. The absence of this coating in modern systems fed by steam generated and delivered directly for heating purposes has in some cases resulted in more corrosion than where exhaust steam was previously used. The remedy for this is to reduce the free oxygen and carbonic acid in the boiler make-up water to a minimum, and keep the system tight as far as possible.

Waters of certain compositions throw down a protective deposit of organic or inorganic material on the inside surface of pipe, which has a marked effect in retarding corrosion. It has been observed that some of the domestic waters of New England are more corrosive since filtration has come into more general use.

Another instance of natural scale forming is found where water from the Great Lakes is heated for domestic use or power purposes. A thin scale is usually found on the inside of pipes which carry this water; the average of several analyses of such scales collected by the author gave:

Iron	28.4 per cent.
Lime, $CaCO_3$	3.0 per cent.
Silica	4.8 per cent.

The lime and magnesia are usually present as bicarbonates in

[4] Bureau of Standards Circular No. 80, "Protective Metallic Coatings for Rust-proofing of Iron and Steel," October, 1919.

these waters, and when heated a portion of the half-bound CO_2 is removed, resulting in precipitation of some of the lime. The silica found in these scales is probably precipitated by reaction with colloid ferric hydrate which always forms a large proportion of these scales. The study which the writer has made of pipe corrosion with various domestic waters has shown that there is a marked difference in the life of pipe in certain localities—one of the most noticeable contrasts in this respect is between the rate of corrosion of pipe used in the Great Lake cities where a comparatively hard scale-forming water is used, in comparison with the action of domestic water of New York or New England, which is relatively purer and softer. Generally speaking, hot-water pipes under the former conditions last two or three times as long as in the latter, other factors being the same.

It is quite possible that some practical means will be developed to give domestic water this scale-forming property without making it objectionable in other respects. Some research work on this problem has been under way for a year or so in our laboratory, which indicates that while such protection is incomplete compared with deactivation of water, that it is possible to form a coating on the inside of pipes under certain conditions, which will cut down corrosion sufficiently to prevent all but a slight discoloration of the water.

DISSOLVED OXYGEN IN WATER.

The controlling influence of free oxygen on corrosion in water is clearly indicated by the electrolytic theory and has been repeatedly demonstrated by experiments and confirmed by practical experience (Fig. 3). The solubility of oxygen in pure water follows the Law of Henry, which states that the solubility of a gas at a given temperature is proportional to the pressure of the gas above the solution. Expressed as a vapor pressure law, this means that the partial pressure of a volatile solute from a solution is proportional to its molecular fraction or to its concentration.

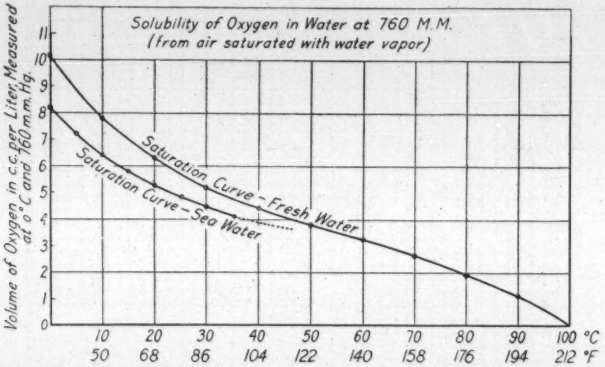
The solubility of oxygen in salt and fresh water at atmospheric pressure varies with the temperature as indicated in the chart (Fig. 1).

The chart shown in Fig. 2 was prepared by Mr. T. M. Knowland for a report for the National Tube Company from

work in the Massachusetts Institute of Technology Research Laboratory and will be found useful for calculating the amount of oxygen dissolved in water from air at any temperature or pressure.

The solubility of iron in water is usually so low that in the absence of oxygen, corrosion is negligible except, as we have pointed out before, where the concentration of H ions is considerable and is maintained by some means, in which case such corrosion cannot be ignored. However, this condition is rarely found in domestic water and but occasionally in water used for

FIG. 1.



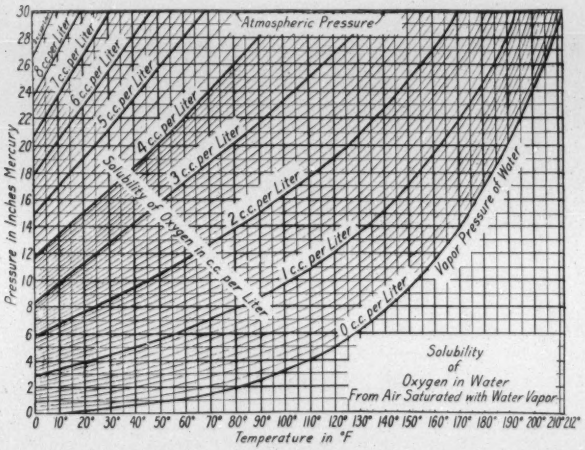
power purposes. In these cases the acid or acid-forming compound, which is usually magnesium chloride, may be neutralized by the addition of lime.

Fig. 3 shows in diagramatic form results of a series of weighed tests of corrosion in water, made under constant conditions but with varying oxygen contents. The water was passed continuously through a series of steel cylinders (Fig. 4), in which were placed varying amounts of perforated steel sheets so that the oxygen content of the water was reduced by stages.

The problem of protection of metal pipes or tanks carrying water is therefore one of removing the free oxygen from the water before it enters the system and preventing further supply of oxygen. To secure practical immunity from attack, it is not

necessary to remove all the free oxygen; the amount which may be tolerated depends on the temperature and amount of water passing through the system. For example, a hot-water service system for a building where water is used at 135° will show no serious corrosion with an oxygen content of 1.0 c.c. per litre; at 170° F., to get as good results, the oxygen contents should not be over one-half of this, or 0.5 c.c. per litre; and in the case of a boiler economizer operating at 300° F., the residual oxygen would probably have to be reduced to 0.2 c.c. per litre to reduce

FIG. 2.


Atmospheric Pressure
8 c.c. per Liter
7 c.c. per Liter
6 c.c. per Liter
5 c.c. per Liter
4 c.c. per Liter
3 c.c. per Liter
2 c.c. per Liter
1 c.c. per Liter
0 c.c. per Liter
Solubility of Oxygen in c.c. per Liter
Vapor Pressure of Water
Solubility of Oxygen in Water From Air Saturated with Water Vapor
Pressure in Inches Mercury
Temperature in °F
0 10° 20° 30° 40° 50° 60° 70° 80° 90° 100° 110° 120° 130° 140° 150° 160° 170° 180° 190° 200° 210° 212°
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30

corrosion to a negligible amount. There are other factors, of course, which make this estimate only approximate, but as it is a more difficult and costly matter to remove the last one-half c.c. of oxygen per litre from water, the degree of removal required is one of the main considerations in determining the selection of the most suitable and economical apparatus for any particular case.

Oxygen removal apparatus has been developed to a high degree of efficiency in this country during the past six years as a result of various designs which have been worked out in service.

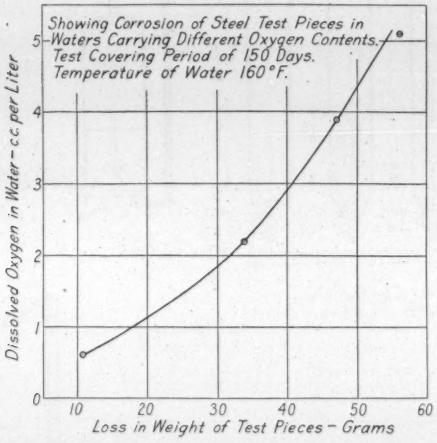
These may be divided into three classes, according to the principles employed:

1. Apparatus for oxygen removal by chemical means.
2. For oxygen removal by mechanical or physical means.
3. Combinations of the above in the same plant.

OXYGEN REMOVAL BY CHEMICAL MEANS (DEACTIVATION OF WATER) IN THE UNITED STATES.

We have frequently noticed that in service more corrosion is found near the inlet to a pipe system than farther away; that in boilers there is more corrosion near the feed-water entrance;

FIG. 3.

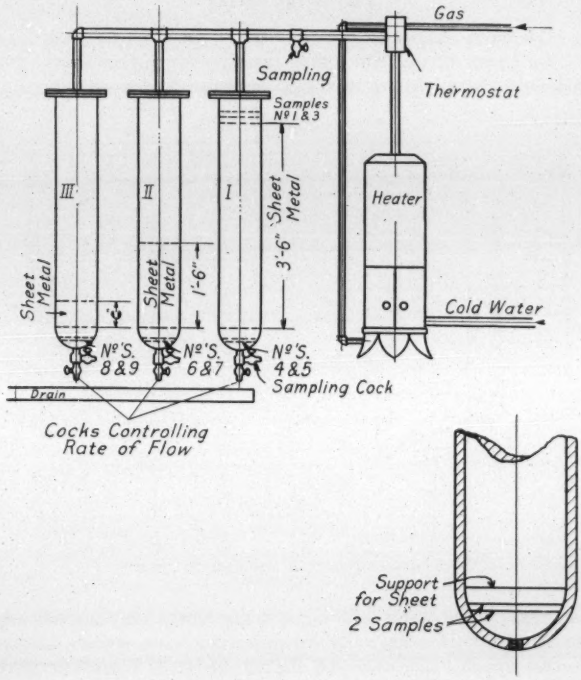


and that in hot-water *heating* systems where only a relatively small amount of water is added each season, no serious damage occurs. Such experience and the viewpoint of corrosion given by the electrolytic theory, led the author to experiment in 1906 with the removal of free oxygen from water by means of contact with a large surface of scrap iron for which apparatus was built in the Research Laboratory of the National Tube Company. Favorable results were obtained, but continuous operation of such a plant over a long period of time required considerable experimental work on a working scale, and it was not until 1915 that

a satisfactory plant constructed on this principle was put into working operation in a building in Pittsburgh.[5]

For lack of a distinctive name, the word "deactivator" was adopted to describe such an apparatus, for water after having

FIG. 4.



Space occupied by sheet metal (26 gage). Tank No. 1, 33,500 c.c; No. 2, 14,366 c.c; No. 3, 4790 c.c.

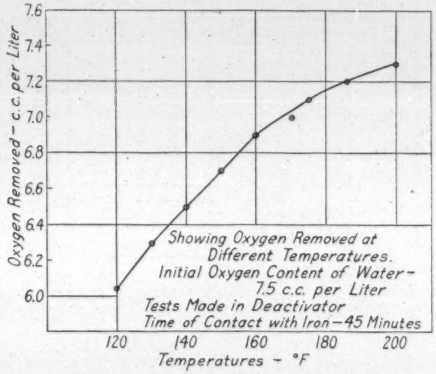
most of its dissolved oxygen removed in this way, has been found to be *inactive* toward iron. The deactivating tank is preferably filled with a special type of expanded steel lathing (about

[5] Described by the Author as "A Method for Practical Elimination of Corrosion in Hot Water Supply Pipe," *Proc. A. S. H. and V. Engineers*, vol. 23, 125, 1917.

26-gage), so formed that the individual sheets will not lay so close as to cause excessive resistance to flow. Miscellaneous steel turnings usually rust together in a tight mass in time so as to seriously interfere with flow. Figs. 5 and 6 show the influence of varying temperature on deactivation. The density of the steel, as expressed in square feet of surface per cubic foot of volume, is another important factor affecting the rate of oxygen removal by this method.[6]

A later form of deactivator installed in an apartment in Boston in 1917 is shown in Fig. 7. A filter was provided in order to

FIG. 5.

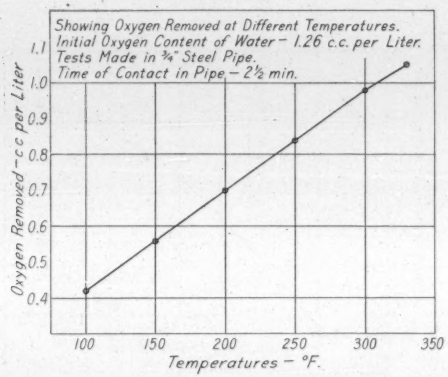


secure clear water free from iron hydroxide; the iron found in solution in the filtered deactivated water is usually less than 0.2 p.p.m. Experiments conducted by Dr. W. H. Walker and his associates at the Massachusetts Institute of Technology, Industrial Research Department, on coagulation of iron in deactivated water, developed the fact that by rendering the water slightly alkaline to phenolphthalein, the colloidal iron could be readily coagulated, and that passing water through a slightly soluble form of granular magnesium oxide was a very convenient means for accomplishing this result. This gave a simple and automatic

[6] U. S. Patents No. 900,323, No. 1,204,602, No. 1,274,099 (F. N. Speller) refer to the application of this principle to the removal of free oxygen from water.

control of coagulation, which materially increased the efficiency of the filter. This experience suggested to the author the possibility of flocculating the hydroxides of iron to such an extent that they would be retained on the expanded sheet steel of the deactivating tank. Experimental work on the influence of temperature, rate of flow, and alkalinity on the production of clear deactivated water, showed that with a certain relation between these factors good results could be accomplished. The most favorable conditions under which clear deactivated water can

FIG. 6.



be obtained in service without the use of a filter have been developed by tests on plants in operation, including the one shown in Fig. 7, which now operates without the filter. Fig. 8 shows the latest form of apparatus for this service in which the filter may be omitted or by-passed as desired.[7] However, the rate of consumption of hot water in some buildings is so variable that a filter may be necessary in some cases in order to secure perfectly clear water at all times.

EUROPEAN PRACTICE.

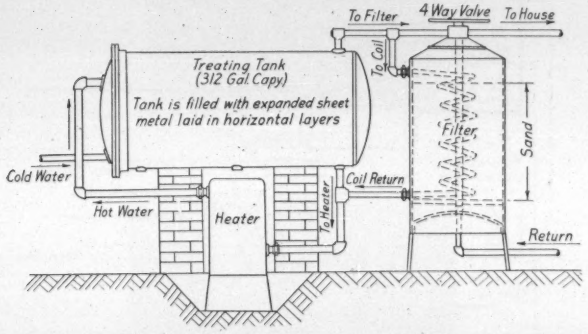
Another form of apparatus for removing dissolved oxygen by use of steel scrap has recently been brought out by Kestner and Paris in Europe and is described in a paper by G. Paris.[8]

[7] Designed by the Anti-Corrosion Engineering Co. of New York.

[8] "Les Corrosions Du Fer et leur Suppression par le Dégazage de L'eau," *Chimie et Industrie*, vol. 6, No. 1, July, 1921.

The novel feature claimed for this is intermittent and reversible flow, based on the assumption that ferric hydroxide is reduced to the ferrous form when allowed to stand in contact with iron and water for some time. Under these conditions the iron hydrates lose their reddish color to some degree, but we have not found them to be more active in this form even after the deactivator has been allowed to stand at rest for 30 hours. Moreover, most of the plants constructed in this country have operated with periods of rest of at least several hours each day with no perceptible regenerating influence, so that while we have found a slow falling off in activity, the deactivator has been

FIG. 7.



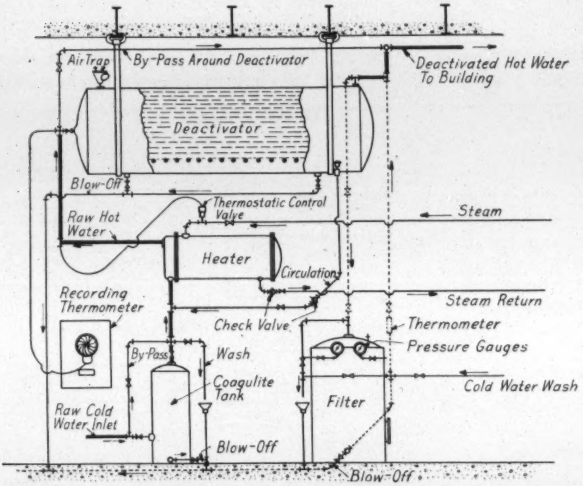
Water heater and deactivator for apartments in Boston.

found to function for as long as four years without renewal with satisfactory results. The author is inclined to believe that the change in color of ferric hydroxide from red to black on standing is due to dehydration rather than to reduction to the ferrous form. However, in this connection, attention should be called to the fact that freshly precipitated ferrous hydrate removes dissolved oxygen from water with great rapidity compared with iron; for instance, Mr. R. G. Knowland, in our research laboratory in 1918, found that freshly precipitated ferrous hydrate combines with all the oxygen in water at 160° F. in a few seconds, whereas steel sheets packed with surface density of 70 square feet per cubic foot of space required at least 40 minutes' contact to

remove 80 per cent. of the oxygen at this temperature. The advantage of the steel sheet method, however, is that it is entirely automatic and will operate for two years or more in a properly proportioned plant without more than casual attention by unskilled help.

A type of deactivator very similar to some of those which

FIG. 8.



Hot water deactivator. Heavy lines indicate course of water when not using filter. Light lines indicate by-passes and other necessary connections.

are in operation in this country has been brought out recently by the Metropolitan-Vickers Electric Company of England and another by Hulsmeyer in Germany for power plant purposes, but so far as the records go, none of these have been put to more than very limited use as yet.[9]

RESULTS OF REMOVAL OF OXYGEN BY IRON IN SERVICE.

Twenty or more of such plants have been put into operation to protect the hot-water piping systems of large buildings in the United States during the past two years. There is no practical

[9] *Ibid.*

difficulty that has not been overcome in operating such plants. The residual oxygen may vary from zero to about .75 c.c. per litre during certain parts of the day without doing perceptible damage. It is more difficult to remove the last traces of oxygen which in any case have a negligible influence from a practical standpoint, but when the rate of flow slows down, the oxygen is more completely removed and a large volume of deactivated water is thus

FIG. 9.

Raw water.

Deactivated water.

Two-inch wrought iron pipe in service two years in the same building.

available for use at any time. So far, experience indicates that the metal should be removed from the deactivating tank every two or three years, depending on the demands of the system. That which has been only partially consumed may be cleaned and put back with new sheets. Domestic water carries on the average for the year 10 p.p.m. of oxygen by weight which will consume about 0.2 pounds of iron per 1000 gallons, which represents a saving of that much iron in useful form in the more inaccessible

parts of the plant. Fig. 9 illustrates the difference between two pieces of the same pipe after three years' service with natural and deactivated water.

DEAERATION BY MECHANICAL MEANS.

Experimental work on oxygen removal at low pressure and high temperatures with which the author has been associated, usually gave an oxygen content lower than the theoretical figure, due to corrosion of the apparatus. With sufficient time and where the water is broken up by spraying or passing over baffles, the theoretical minimum oxygen can always be obtained. Many tests in service have indicated that most of the common types of open feed water heaters when properly vented and operated without excessive load will give approximately the theoretical minimum of oxygen as indicated in saturation curves (Fig. 1).[10]

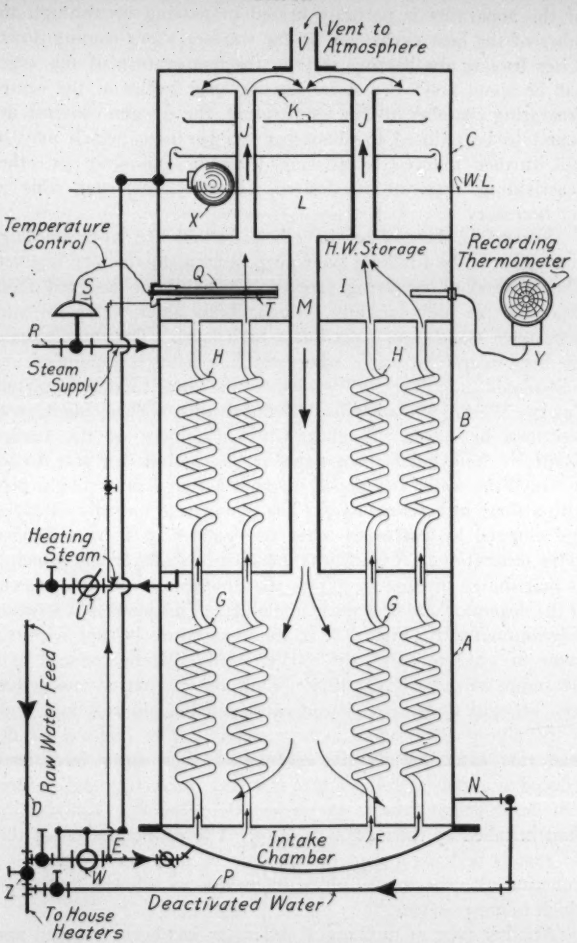
It is a comparatively easy matter to remove 80 per cent. of the dissolved gases by mechanical means but very difficult to remove the last 5 per cent., so that, as in the case of chemical deactivation, before designing a plant it is important to determine what amount of residual oxygen will be harmful under stated conditions. This depends on the temperature, volume of water handled, and other factors, and must be estimated for any particular set of conditions before undertaking the design of deaerating equipment. The deaerating efficiency desired will evidently have much to do with determining the most economical form of apparatus to use. A few types which have been developed and tried out will be described briefly.

DEAERATION OF HOT WATER.

A simplified form of deaerator, developed by the Anti-Corrosion Engineering Company of New York, is shown in Fig. 10. This operates at atmospheric pressure and consists of three essential parts which may be combined in one shell as indicated in Fig. 10. These are: A heater, heat exchanger, and deaerating chamber. An ingenious method of temperature control is provided which is desirable for efficient operation so that the temperature will not vary more than 3 or 4 degrees from 208° F. at any time.

[10] The Author is indebted to Mr. G. H. Gibson of the H. S. B. W.-Cochrane Corporation, Philadelphia, Pa., for considerable data on this point which were obtained from heaters in operation.

FIG. 10.



Deaerator operating at atmospheric pressure.

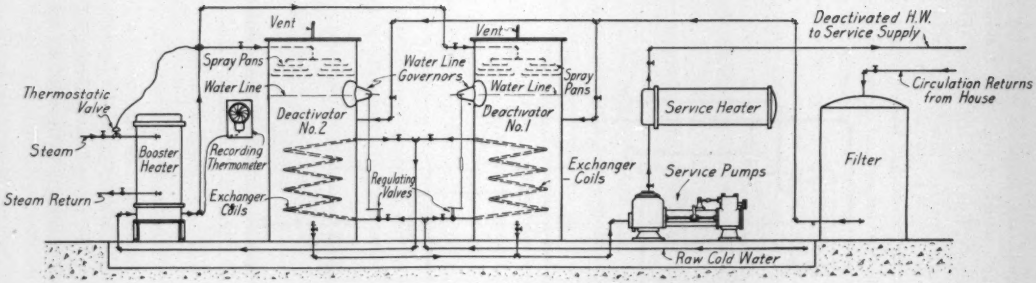
The cold water entering at the point shown near the bottom of the apparatus is partially heated in passing up through the tubes of the heat exchanger by the warmer water coming down. After leaving the heating section, the temperature of the water will be about 208° F. After passing over baffles of the vented deaerating chamber at this temperature, the oxygen contents are found to be reduced to about 0.4 c.c. per litre, which may be still further reduced by passing through zinc scrap or other deactivating material if desired. Usually, however, this is not necessary.

Several of these plants have been installed in large buildings and appear to be fulfilling their purpose in a satisfactory manner. This method of removing free oxygen has been designed from experience in high buildings which obtain their water pressure from open stand-pipes placed at a high level. The same scheme has been adapted to cases where the hot water is repumped and recirculated as in the plant installed for the Girard Estate Passyunk Power Plant, Philadelphia, Pennsylvania. This plant was described by Robert Hughes, Chief Engineer of the Girard Estate.[11] It includes a hot-water service system for 500 houses to which the water is pumped through a four-inch wrought pipe with a three-inch return loop. The piping was so badly damaged and clogged by corrosion after ten years that it was decided to try deaeration. A plant was installed in 1920, on the principle of that shown in Fig. 10, except that the heater was independent of the deaerator and heat exchange units. This plant is illustrated diagrammatically (Fig. 11). The temperature is kept within a range of 194° to 210°, the oxygen being thereby reduced to a maximum of 0.5 c.c. per litre. They report that corrosion has been brought under complete control and the old rust and scale in the piping removed to a large extent. The removal of the hard rust after the oxygen contents of hot water have been reduced at about 0.5 c.c. per litre is a very interesting and unforeseen development which was observed in the first deactivating plant installed by the author in 1915. The disintegration of this old rust is perhaps due to dehydration or may also be due to a reduction of some of the ferric hydroxide to a lower hydroxide which is more soluble.

Another type of mechanical deaerator has been designed and

[11] *Journal Am. Soc. H. and V. Engrs.*, March, 1921, p. 107.

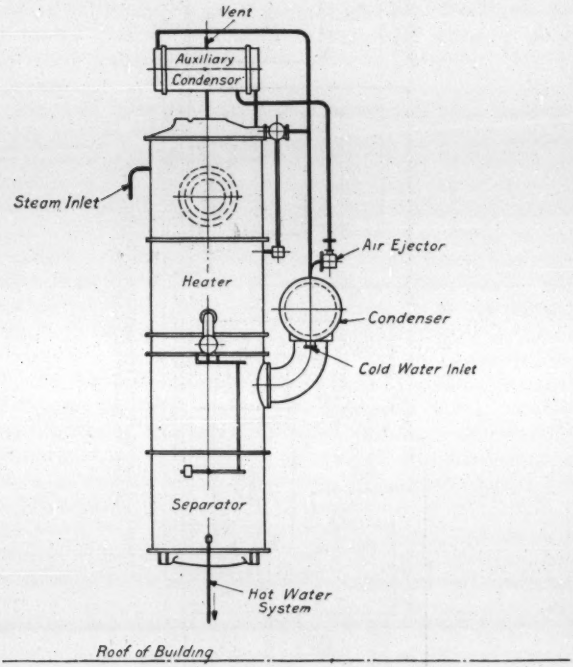
FIG. 11.



Deaerators—Passyunk Central Heating Plant, Philadelphia, Pa.
(Designed by Anti-Corrosion Engineering Co.)

built by W. S. Elliott, one form of which for large buildings is illustrated (Fig. 12) which operates as follows: Raw water is taken from the supply line and conducted through the cooling circuit of the main surface condenser, which is designated

FIG. 12.



Deaerator operating at reduced pressure.

in the diagram as "condenser." From the surface condenser the water passes to the heater, the flow of the greater portion of it being controlled by the inlet valve of the heater. A small portion of the water is by-passed to the heater through the cooling circuit of a small surface condenser, designated as an "auxiliary con-

denser," the function of which is to condense the steam used in the air ejector and recover the heat.

From the heater the water flows by gravity to the separator, the rate of flow being controlled by the inlet valve of the separator. In the separator, the air is removed by suddenly introducing the heated water into a region of vacuum in which the vapor pressure corresponding to the vacuum is lower than that corresponding to the temperature of the entering water. The water boils explosively, its temperature is lowered to the temperature of the vacuum and the dissolved gases separated. Some portion of the water is evaporated into steam in the separation process and the rest of it flows into the service pump line. The portion which has flashed into steam, mixed with the separated gases, is drawn into the surface condenser which is attached to the separator shell where the steam is condensed and the condensate returned to the separator; the heat of the steam is returned to the cooling water, and the non-condensable gases are removed by steam jet air ejector. From the separator, the hot deaerated water is delivered to the hot-water service line.

When correctly designed and operated at the proper rate, it is reported that very low oxygen contents can be obtained with this apparatus. It would seem that this form of deaerator is one that would be best adapted for large power plant work, for instance where it is necessary to keep the oxygen contents of large quantities of feed water below 0.2 c.c. to preserve steel economizers. One has been installed quite recently in the Delaware plant of the Philadelphia Electric Company.

DEAERATION OF COLD WATER.

Water at normal temperature usually has a comparatively low rate of corrosion and does no serious damage to galvanized pipes within 20 or 30 years, but there are exceptional locations where the cold water is more active or where the corrosion which does occur causes considerable inconvenience through clogging of the system with a bulky form of rust.

Then again cold salt water is more active than fresh water and causes considerable damage in the seaside hotels, bath houses, and in large condensing plants. Such corrosion can usually be reduced to a negligible amount by deaeration. The process of deactivation by steel scrap is usually too slow and therefore not economical for water at normal temperature, so that for such

conditions we are forced to use a high vacuum apparatus. By reference to the diagram, Fig. 2, it will be seen that with a vacuum of 23 inches of mercury, about 80 per cent. oxygen removal may be accomplished with water at 65° F., which is as much as should be needed; in fact, a much lower percentage deaeration would, no doubt, suffice in most cases.

Incidentally it may be of interest to note that deaeration has been usefully applied to cyanide solutions used in the extraction of gold. In 1916 Thomas B. Crowe patented a "Process of, and Apparatus for, Precipitating Materials from Solution" (U. S. Patent Nos. 1,281,249 and 1,321,985), in which the essential element is the deaerating of the gold cyanide solution by means of a vacuum deaerator before the solution is treated with zinc for the precipitation of the gold. Removal of the dissolved oxygen from the solution prevents the formation of zinc oxide, which is said to save about 50 per cent. of the zinc and cyanide formerly used. The Crowe Process, as it is now called, was first installed at the Portland Mill at Colorado Springs, Colorado, but has since been put in use at other mills in the United States and abroad. The chemical reaction taking place in precipitating the gold may be represented as follows:

$$KAu(Cn)_2 + Zn + H_2O = Zn(Cn)_2 + Au + H + KOH.$$

When dissolved oxygen is present, it has been found that zinc oxide is formed and that considerable excess KCn is required to completely precipitate the gold.

Deaeration for prevention of corrosion of a 30-inch steel main at a maximum temperature of 85° F. has been successfully applied on a large scale in the Coolgardie Mining District, Western Australia.[12] This water, which is highly corrosive, is sprayed into a chamber under high vacuum. After operating for a few years, the results show that the deaerator extracts about 80 per cent. of the dissolved oxygen and the corrosion activity is reduced by this means to about one-quarter of the original amount. The residual oxygen is removed after passing through about 30 miles of this pipe, after which the corrosion is reported to be negligible from observations made on steel test pieces. This water carries a small amount of magnesium chloride, otherwise corrosion would, no doubt, be still further reduced by deaeration.

[12] A description of this apparatus is found on pages 83 and 84 of a paper by O'Brien and Parr on "The Coolgardie Water Supply," *Inst. of C. E.*, vol. 205, Session 1917–1918, Part I.

EUROPEAN PRACTICE IN MECHANICAL DEAERATION.

Mr. G. Paris, in his paper on "Corrosion of Iron and Its Suppression by the Degasifying of Water,"[13] gives the most complete account which has yet been published of work which has been done on this problem in Europe, most of the practical end of which has been done during the past few years. He points out the drawback of degasification under high vacuum due to the difficulty of holding the vacuum in apparatus of a large size and that the minimum oxygen content is limited by the saturation point of water for any particular temperature and pressure. Evidently his experience has not been so favorable as we have found with apparatus of this class.

Several types of open feed water heaters, and deaerating apparatus, are described for extracting excess gas from water under pressure, with some new devices for separating gases mechanically from hot water under vacuum. The laws of solubility of gases in water indicate that to attain sufficiently low oxygen to prevent corrosion, the temperature should be at or near the boiling point for any particular pressure which in practice requires a prohibitive temperature, where the pressure is high, so that it has been found most economical to work deaerators at atmospheric pressure or lower.

The apparatus made by "Balke," of Bochum, Germany, for the extraction of gases from hot or cold water seems to have given good results. The water at normal temperature is violently sprayed into a chamber carrying a 90 per cent. vacuum, the disengaged gases being drawn off by an air pump into a condenser. The following results have been published in Mr. G. Paris' paper (*ibid*):

	Amount of O_2 in cu. cent. per litre.		Amount of CO_2 in cu. cent. per litre.	
	Before Degasification	After Degasification	Before Degasification	After Degasification
Installation of 50 cu. metres, 90 per cent. vacuum, average temp. 20° C...	11.56	0	1.34	0
Installation of 50 cu. metres, 90 per cent. vacuum, average temp. 26° C...	8.6	0.03	19.65	0

[13] *Chemie et Industrie*, July, 1921.

The Coolgardie deaerator operating with water at a maximum temperature of 85° F. is reported to give over 80 per cent. extraction of gas at high vacuum. The residual oxygen reported with the Balke apparatus operating cold seems altogether too low to be attained under conditions described.

The "Balke" apparatus for degasifying hot water, several of which are reported to have been built, consists of: A horizontal tank with transverse vertical partitions so arranged as to cause the water heated by steam in the first compartment to pass up and down through a circuitous course. The gases given off are collected by a manifold connected to the top of each compartment into a common main. It will be seen that this is practically an open type feed water heater. The treated water is passed into a closed tank where it is kept out of contact with air by an atmosphere of steam or nitrogen. The following results are reported operating at 100° C. (*ibid.*):

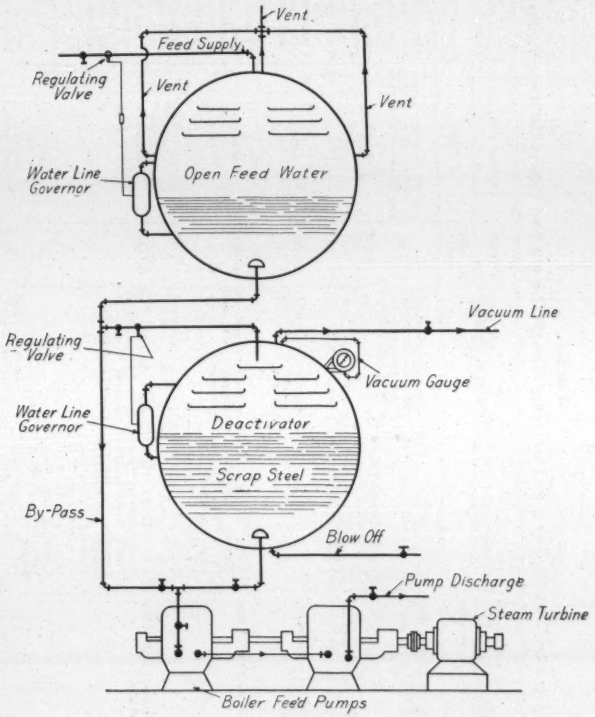
Installations	Amount of O_2 in c.c. per liter.		Amount of CO_2 in c.c. per liter.	
	Before Degasification	After Degasification	Before Degasification	After Degasification
Centrale Électrique de Trèves	10.50	0.22	1.13	0.00
Mine Adolphe	6.56	0.00	5.00	0.40
Westerwald	5.90	0.00	1.50	0.00

COMBINATION OF MECHANICAL AND CHEMICAL DEAERATION.

It is obvious from the laws governing the solubility of gases in water and experience with deaerators built on this principle, that the percentage of oxygen removal possible is limited to the theoretical saturation point of oxygen in water at any particular temperature and pressure, whereas chemical deactivation when given sufficient time will go on at any temperature and pressure until all the available oxygen is exhausted. It would therefore seem that where very large volumes of water have to be completely deaerated, or nearly so, an economical type of apparatus would be one in which the bulk of the free oxygen, which is easy to remove, is extracted by some simple and economical form of deaerator and the residual oxygen, say the last 5 or 10 per cent., by chemical treatment. The latter may be accomplished by a few minutes' contact with a suitable form of sheet iron scrap or by reac-

tion with ferrous hydrate from the addition of ferrous sulphate and lime. The action of ferrous hydrate is almost instantaneous but requires a reliable proportional feed of reagents. The

FIG. 13.



Combined deaerator and deactivator for boiler feed water.

combination of sheet iron deactivator with a preliminary deaeration has been employed in treating the hot water of one of the largest apartment houses of New York (Park Avenue and 48th Street). The water for the hot-water supply system is first put

TABLE I.

Summary of Results of Investigations of the Corrosion of Wrought Iron and Steel Pipe in Hot Water Supply Service.

Time Removed	Where Test Was Made	Length of Time Pipe Lines Were in Service	Authority and References	Number of Cases on Record	Average of Deepest Pits, Inches		Conclusions
					Wrought Iron	Steel	
1921	West 41st St. Public Baths, New York City.	4 yrs., 6 mos.	Chas. Baskerville, Prof. of Chem., College of the City of N.Y. Reported June 22, 1921.	Fourteen sections of steel of three different makes, 6 sections of wrought iron pipe.	0.0592	Lot (1) ——— 0.0497 Lot (2) ——— 0.0535 Lot (3) ——— 0.0544 Average 0.0525	"Wrought iron showed deepest pitting. Appearance of corroded surfaces was characteristic—wrought iron showing isolated 'pits', steel, a more general corrosion with 'lakes' well distributed with more or less uniformity. The more uniform corrosion of the steel is a fact of no little importance."
1921	West 41st St. Public Baths, New York City	10 years		Five sections of steel, 1 section of wrought iron pipe.	0.0606	0.0532	
1921	William Penn Hotel, Pittsburgh, Pa.	4 yrs., 7 mos.	Jas. O. Handy, Dir. Special Investigations, Pgh., Testing Lab. Reported July 11, 1921.	Four sections each of wrought iron and steel pipe.	0.1095	0.094	"Such differences, which confirm previous tests, are conclusive as to the relative resistance to corrosion of steel and wrought iron pipe in hot water lines."
1919	Irene Kaufmann Settlement, Pittsburgh, Pa.	2 yrs., 7 days	Jas. O. Handy, Technical Director, Pittsburgh Testing Laboratory. Report made to Resident Director Teller, Jan. 22, 1920; p. 97, Jan., 1920, A. S. H. & V. Engrs.; p. 276, Mar., 1920, A. S. H. & V. Engrs.	Fifteen lengths of steel, 15 lengths of wrought iron arranged alternately.	0.1144	0.1095	"These figures show that no marked distinction is possible between the rate of corrosion of the steel and the iron pipe."

1919	Harvard University, Cambridge, Mass.	3 yrs.	Melville C. Whipple, Prof. of San. Chem., Harvard University, Jrn'l New England Water Wks. Assn., p. 42, Mar., 1920.	Two sections each of scale-free (steel); galvanized steel, copper steel and wrought iron pipe.	0.073	Scale-Free 0.045 Copper Steel 0.068 Galvanized 0.078	"Judging from the depths of pitting and the general appearance of the inside of the pipe, it was evident that, so far as the conditions of this particular experiment with the Cambridge hot water service were concerned, scale-free pipe had suffered less real damage than any of the others after three years' exposure."
1918	Brown University, Providence, R. I.	11 mos.	Wm. F. Kenerson, Professor of Mechanical Engineering, Brown University. Report made June 7, 1918. Bulletin 2—"Corrosion of Hot Water Piping." National Tube Company.	Two sections each of black and copper steel and wrought iron; one section each of galvanized and copper steel, galvanized.	0.0674	Black Steel 0.0544 Copper Steel 0.0639 Galvanized 0.0547 Copper Steel Gal. 0.0938	"There is evidently no marked superiority of either the wrought iron or steel for the test conditions described. . . . The wrought iron failed first by developing the deepest pits. The steel developed a greater number of shallower ones."
	This test was conducted in four different places as follows:						
1917	(A) West 41st St. Bath, New York. (B) East 76th St. Bath, New York. (C) East 109th St. Bath, New York. (D) Cherry and Oliver Sts. Bath, New York	(A) 2 yrs., 9½ mos. (B) 2 yrs., 5 mos. (C) 2 yrs., 6 mos. (D) 2 yrs., 6 mos.	James S. Macgregor, Instructor in Civil Engineering, Columbia University. Report made Jan.—March, 1917. Bulletin 2—"Corrosion of Hot Water Piping." National Tube Co.	(A) 3 sections each of wrought iron and steel pipe. (B) 4 sections of steel and two of wrought iron (C) Same as test B. (D) One section each of steel and copper steel.	(A) 0.057 (B) 0.075 (C) 0.035	0.052 0.070 0.035 (D) Steel 0.021 Copper Steel 0.022	Taking the total averages of steel (which include scale-free and copper steel, as well as ordinary black) pipe as against those for iron in the four tests, we find the latter to have pitted deeper by 0.025 in., which indicates in favor of steel pipe in these particular tests.
1916	Irene Kaufmann Settlement, Pittsburgh, Pa.	10 mos.	Jas. O. Handy, Technical Director, Pittsburgh Testing Laboratory. Report made October 31, 1916. P. 125, 1917 Trans. of A. S. H. & V. Engrs.	Seven sections of steel and 4 of wrought iron pipe.	0.116	0.110	The author states that a certain sample of wrought iron showed the most general corrosion, while a steel section showed the greatest number of separate pits. No direct reference to comparative corrosion is made.

through a deaerator of the type shown in Fig. 10, located a little below the stand-pipe on the roof, and is then brought down to a steel deactivator in the basement before entering the system. This gives almost perfect protection to the hot-water pipes. Another design for a combination plant for power plant service is shown in Fig. 13 [14] which includes an ordinary vented open-type heater from which the water is passed into a tank at lower pressure but not so low as to boil the water, so that no condenser is required. The residual oxygen amounting to about 0.5 c.c. per litre is finally extracted by passing through steel scrap placed in the lower part of the vacuum tank. A vacuum control apparatus is attached.

CONCLUSION.

From this outline of the present status of corrosion prevention by deactivation and deaeration of water, the reader may gather some idea of the important application of these principles to the conservation of iron and other metals in closed systems—*for what has been said of the protection afforded to iron applies equally well to brass and other metals which are subject to attack by water.* As a rule, cold water does not seriously attack pipes or tanks in the life of a building or pipe line, but there are notable exceptions to this rule. The experience with the Coolgardie (West Australia) 30-inch pipe line and the satisfactory results of partial deaeration show that this method of protection can in some cases be economically applied to cold water when necessary. This would seem to apply particularly to cold as well as to hot salt water used in large seaside hotels, which cause considerable damage and costly repairs. While the laws underlying corrosion are now fairly well established, the economic application of these laws require a detailed knowledge of existing conditions interpreted in the light of previous experience as in all engineering development. Much yet remains to be done in perfecting details, but the results already obtained are sufficient to indicate the permanent benefits to be derived through the application of these principles.

---

[14] Designed by the Anti-Corrosion Engineering Company, New York, U. S. A.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

NOTE ON THE PREPARATION OF MANNOSE.[1]

By E. P. Clark.

[ABSTRACT.]

SIFTED ivory nut shavings are added to 10 times their weight of boiling 1 per cent. sodium hydroxide solution. The mixture is at once removed from the source of heat and stirred occasionally during the ½ hour. The shavings are then washed thoroughly with running water until neutral and clear, and dried.

Five hundred grams of the material, thus prepared, are thoroughly mixed with 500 grams of 75 per cent. sulphuric acid and allowed to stand until the next day. This mass is dissolved in water, making a volume of 5.5 litres, and boiled under reflux for 2½ hours. While the liquid is still boiling, it is neutralized with a thin paste of precipitated barium carbonate. The solution is at once filtered through a thin layer of active carbon placed on moistened filter paper in a Büchner funnel. The filtrate generally contains a little barium, probably in combination with organic acids. This is removed by adding a few c.c. of dilute sulphuric acid until no further precipitate is formed. The barium sulphate is filtered off and the solution evaporated under reduced pressure to 87–88 per cent. total solids. An equal volume of glacial acetic acid is added and thoroughly mixed by warming and shaking. The syrup is seeded, placed in an ice box over night for crystallization to start, and it is then frozen with an ice-salt mixture. The frozen mass is placed in a refrigerator at or near 0° C., where it will thaw out slowly. After about a day the greater portion of the sugar will often have crystallized, but generally a week is required for complete crystallization. The yield is uniformly 42–45 per cent. of the treated meal used.

* Communicated by the Director.

[1] Scientific Papers No. 429.

HIGH-FREQUENCY RESISTANCE OF INDUCTANCE COILS.[1]

By G. Breit.

[ABSTRACT.]

FOR direct current the resistance of inductance coils can be defined by means of Ohm's law. At high frequencies Ohm's law does not give complete information about the current flow, because the current flow is modified by induction effects of magnetic as well as electrostatic nature. As a result the current density is not uniform over a given cross-section of a wire, nor is it the same for different cross-sections of the wire. The study of non-uniformity of current density in a cross-section is the subject of skin effect, which is not discussed in this paper, although the well-known results as to skin effect are used.

The non-uniformity of current with respect to different cross-sections has not been treated before to any extent. It is the purpose of the investigation described in this paper to calculate the effects of this non-uniformity and also to measure them. The non-uniformity with respect to different cross-sections is caused by the capacities distributed along the winding of the coil. These capacities cause charges to collect at various points on the wires of the coil, and this results in the current having different values at different points in the coil.

There are several effects of the non-uniform distribution of current along the wire. The most important, however, is the increase in the resistance of the coil with the frequency. An expression for the resistance of an inductance coil is derived which takes into consideration both the skin effect and the capacity effect for the case of a short, single-layer solenoid, and the formula is verified experimentally.

The other effect considered is that of the relative importance of emf's having the same value but impressed at different points of the coil. The emf is more effective in setting up current at all points of the coil when it is impressed at a current loop.

It is also shown that the resistance as measured by the resistance-variation method with respect to different points in the coil depends in a definite manner on the current distribution. If

[1] Scientific Papers No. 430.

R_1, R_2 are the measured values of resistance and if i_1, i_2 are corresponding values of the current, then

$$i_1\sqrt{R_1} = i_2\sqrt{R_2}$$

provided the coil can be considered as made of a nearly perfectly conducting material.

It is also shown that at a given point of the coil the current i_0 may be computed if the emf induced in any coil portion is known and if the value of the resistance measured by the resistance-variation method is known for all points of the coil. These computations are then applied to coil aerials and the results are verified experimentally.

EFFECT OF HEAT-TREATMENT ON THE MECHANICAL PROPERTIES ON ONE PER CENT. CARBON STEEL.[3]

By H. J. French and W. George Johnson.

[ABSTRACT.]

THIS paper gives the effects of varying time-temperature relations in heat-treatment on tensile and impact properties, hardness, and structure of one per cent. carbon steel as follows: (a) Effect of temperature variations in hardening; (b) time at hardening temperatures both above Acm and between the Ac_1 and Acm transformation; (c) effects of tempering steel hardened in different ways and effects of "soaking" just under the lower critical range; (d) comparison of oil and water hardening for production of definite strengths.

Under the described conditions of treatment and test the following features are observed:

(1) The most suitable oil or water quenching temperature for steel which is subsequently to be tempered at relatively high temperatures is slightly above the end of the Ac_1 transformation.

(2) With increase in oil quenching temperature for steel subsequently tempered at 538° C. (1000° F.) hardness, strength and limit of proportionality increase and maximum values are obtained after quenching from 843° C. (1550° F.) which is coincident with retention of all but a small portion of the excess cementite. A higher quenching temperature results in decreased strength.

(3) When this steel is subsequently to be tempered to produce a tensile strength in the neighborhood of 120,000 pounds per

[3] Technologic Paper No. 206.

square inch water quenching is to be preferred on account of the higher elastic ratio produced, always assuming that the size and shape of material is such as to allow drastic treatment. If higher strength is desired, oil quenching from just above the Ac_1 transformation will give slightly better combinations of strength and ductility but with lower elastic ratio than are obtained by water hardening.

(4) A lower tempering temperature is required after water hardening than when cooling in oil from the same temperature in order to produce the same strength. This difference in temperature in general increases the higher the strength required (the lower the tempering temperatures).

(5) When samples are quenched in water and others quenched in oil and all so tempered as to produce the same strength the water quenched steel will have the highest hardness as determined by the Brinell and Shore methods.

(6) While good combinations of tensile strength and ductility may be obtained by tempering at the higher tempering temperatures the steel is brittle and has low resistance to impact. This is shown by the much higher combinations of strength and ductility obtained in tensile tests when the steel is ground to size after heat-treatment and by the low Charpy and Izod values obtained in all cases.

(7) Increased time at hardening temperatures results in increased hardness, strength and limit of proportionality and decreased ductility as does rise in temperature.

(8) Long time heating just under the lower critical range results in a material softening of the steel, equivalent to a decrease of 40 per cent. in Brinell hardness and 20 per cent. in Shore hardness when the time at temperature is increased from 30 minutes to 5 hours. Short-time heating in this temperature range results in a softer steel than that air cooled from above the transformations.

MANUFACTURE AND PROPERTIES OF STEEL PLATES CONTAINING ZIRCONIUM AND OTHER ELEMENTS.[1]

By George K. Burgess and Raymond W. Woodward.

[ABSTRACT.]

THIS investigation originated from the need of the Ordnance Department of the Army and Navy for information regarding the

[1] Technologic Paper No. 207.

effects of the ballistic properties of light armor plate of certain chemical elements such as zirconium.

A joint program was outlined according to which the Bureau of Mines was to produce and analyze ingots of the desired compositions; the Bureau of Standards to manufacture and heat-treat plates, carry out physical tests, micro-examinations and chemical analyses, and develop methods of chemical analysis, when needed, for the more unusual elements in steel and in the presence of each other; and the Navy Department was to carry out the ballistic tests.

Although the results of the ballistic tests are not available for publication, an account of the mechanical properties and tests of this series of somewhat unusual steels was considered worthy of publication. These results may be summarized as follows:

About 193 heats of steel containing in various combinations the following principal variable elements: Carbon, silicon, nickel, aluminum, titanium, zirconium, cerium, boron, copper, cobalt, uranium, molybdenum, chromium and tungsten, have been studied.

None of the steels presented any difficulties in rolling into plate except those containing boron.

The usual mechanical properties and impact tests were carried out on all of the steels. It is shown that steel containing 0.40 to 0.50 per cent. carbon, 1.00 to 1.50 per cent. silicon, 3.00 to 3.25 per cent. nickel, and 0.60 to 0.80 manganese and deoxidized with a simple deoxidizer such as aluminum can be produced having a tensile strength of approximately 300,000 pounds to the square inch, with excellent ductility and toughness. This type of steel is recommended for a structural material.

Although the same high properties are obtained in steels of the above composition with the aid of additional elements it does not appear necessary to resort to such additions of expensive alloying elements.

Zirconium, like titanium and aluminum, acts primarily as a scavanger, and when it is not removed as part of the slag remains in the steel in the form of square bright yellow inclusions not directly visible at magnifications lower than 500 x. It is not considered that these inclusions can be very beneficial, and if they are segregated and rolled out into thin plate-like streaks they may be detrimental, especially in armor plate.

Of the other elements that are regarded as special alloying ad-

ditions, chromium, tungsten, vanadium and molybdenum go into solution and produce a martensitic pattern in the air-cooled specimens. Cerium and uranium act in a similar manner but also show characteristic inclusions. Copper goes into solution but a larger amount is required to produce a martensitic pattern in the air-cooled samples than for the others. Borons forms a complex eutectic, probably that of an iron-carbon-boron compound with iron. This eutectic is fusible at the temperatures ordinarily used in rolling, but at slightly lower temperatures steel containing boron can be rolled successfully. Hot working breaks up the eutectic and spherical hard particles, similar to iron carbide globules, are formed.

REPORT OF 14th ANNUAL CONFERENCE ON WEIGHTS AND MEASURES.[6]

[ABSTRACT.]

THIS publication is a verbatim report of the Fourteenth Annual Conference on Weights and Measures, an organization composed of state and local officials engaged in the enforcement of weights and measures laws throughout the United States. The conferences are held to promote uniformity in weights and measures laws, rules and regulations, and specifications and tolerances, and the enforcement thereof in methods of inspection of apparatus.

The Secretary of Commerce gave an address pointing out the necessity for proper supervision of weights and measures and the president of the conference and Director of the Bureau of Standards outlined advances made during the year. State and local officials gave reports on conditions in their respective jurisdictions, the majority of which indicated that conditions were gradually improving, that the work was gaining in public importance, and that excellent legislation was being enacted.

Perhaps the most important single accomplishment of the present conference was the adoption of a proposed model law for the sale of bread, the text of this being agreed upon after several papers had been delivered by representatives of the baking industry and of the officials, and a general discussion held. In brief, this law proposes standardization of the loaves and provides

[6] Miscellaneous Publication No. 48.

that bread shall be sold only in loaves weighing one-half pound, one pound, one and one-half pounds or multiples of a pound.

The specifications and tolerances for liquid-measuring devices adopted by the preceding conference were reviewed and several changes were made, the advisibility of which was indicated by the enforcement of the regulations in the field during the year. New tolorances were adopted, two cubic inches being allowed on deliveries of one-half gallon or less, three cubic inches on a gallon delivery, and one cubic inch per gallon additional in the case of deliveries of more than this amount. These serve to increase the former tolerance on small deliveries and decrease it on large deliveries. Also it was provided that the tolerance in excess only is not to be applied to condemn pumps on tests of deliveries made at a more rapid speed than normal speed of delivery. Some of the more important changes in specifications were as follows: Allowing two delivery outlets when deliveries are properly safeguarded; adding the two and one-half gallon size to the allowable capacities for devices; adding to the scope of the regulations by including devices intended to be attached to and used in connection with liquid-measuring devices; and allowing scales with non-parallel lines when proper indication is obtainable. There was a general discussion of the application of retroactive specifications for liquid-measuring devices.

There was referred to the Committee on Specifications and Tolerances for consideration during the coming year and report to the next conference the question of tolerances on bread weights, and specifications and tolerances on heavy-duty automatic scales, fabric-measuring devices, and tank wagons it being developed in discussion that additional regulations for these devices were becoming necessary. Among the resolutions adopted were endorsements of the slack-filled package bill, and of the principles of national serialization of type of apparatus and of the simplification of packages and containers. The metric system of weights and measures was discussed and it was decided to give this subject a prominent place on the program of the next conference.

Some of the other subjects upon which there were papers and discussions were as follows: The mine scale work of the Bureau of Standards; the proper methods of test of liquid-measuring devices; the enforcement of the federal law requiring the marking of the weight on wrapped meats; the general methods of detecting

violations and proceeding against offenders; the destination weighing of coal in car-load lots; and the education of the public to the necessity of accurate weights.

The appendixes contain the specifications and tolerances for liquid-measuring devices as amended by the conference; the text of the model bread law adopted, and a new section on this subject in conformity with the above to be inserted in the proposed general model state law on weights and measures adopted by previous conferences and recommended to the various states for enactment.

SPECIFICATIONS FOR LIME-FLINT GLASS TUMBLERS.[a]

[ABSTRACT.]

SPECIFICATIONS are given for a plain pressed hotel tumbler made of lime-flint glass. The items include the designation, measurements, material, quality, tolerance in size and weight, shock test, boiling test, acceptance, and sampling. They were formulated under the auspices of the Bureau of Standards and have been accepted by the Army, Navy and Marine Corps, Public Health Service, and General Supply Committee of the United States Government. At least 95 per cent. of the samples must pass all tests. The tests include five fillings with boiling water with sample at room temperature at the start (the shock test); and boiling for six hours to disclose any sign of corrosion, scumming, chipping, or cracking (boiling test). Traces of color or bubbles if not unsightly are allowed, but there must be no stones, cords, nor fine cracks. The dimensions, weight, and capacity are specified with the minimum and maximum allowable for each.

An Investigation of the Constancy in Wave-length of the Atmospheric and Solar Lines. C. E. ST. JOHN and H. D. BABCOCK. (*Astrophys. J.*, Jan., 1922.)—A few years ago Perot reported a series of observations on the wave-length of atmospheric lines in the solar spectrum. According to him the wave-length of an oxygen line in the B group increased from morning to noon, after which time it grew less. These results are contradicted by careful measurements made on 25 plates taken at Mount Wilson Observatory. The variation is within the limits of accidental error.

G. F. S.

[a] Circular No. 119.

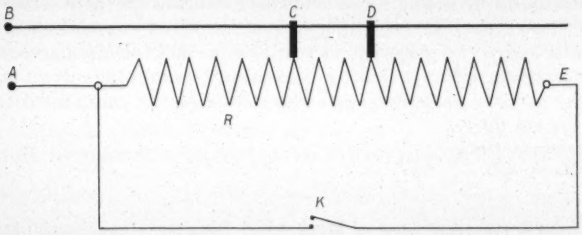
NOTES FROM THE LABORATORY OF PURE SCIENCE NELA RESEARCH LABORATORIES.*

A METHOD FOR INCREASING THE CARRYING CAPACITY OF A RHEOSTAT.

By W. E. Forsythe.

When using an ordinary slide resistance to control a current it often happens that when the current is the largest only a small part of the resistance is being used. This may be disadvantageous for two reasons: In the first place, the smallest change possible in this small part of the resistance may greatly increase the current, and in the second place, the resistance may be very much overheated. To overcome these difficulties a method has been devised

Fig. 1.



whereby it is possible to use both ends of the rheostat and thereby double its carrying capacity and at the same time make current control easier and more accurate. In Fig. 1 is shown diagrammatically a slide rheostat with the additions necessary in order that both ends can be used.

The current ordinarily enters at the binding post A, passes through the resistance R and out at the binding post B through the slide C. As the slide C is moved towards A to increase the current, more and more of the resistance is cut out of the circuit and is not used. To change the rheostat so as to double

* Communicated by the Director.

its carrying capacity put on a second slide, D, a second binding post, E, at the end of the rheostat opposite A and a switch, K, so connected that when it is closed the two binding posts, A and E, are connected. To operate the rheostat proceed in the ordinary manner (switch K open) with the current entering at A passing through the resistance R, the slide C and out at B. To increase the current, move this slide towards A until it has passed over three-fourths of the distance from E to A. To obtain a larger current move both slides to the centre of the resistance R and close the switch K. The resistance will be about the same as it was with one slide and one-fourth of the resistance in use. The current will be divided at A and one-half of it will enter at E and pass out at D, the other half entering at A and passing out at C. To increase the current move either slide C towards A, slide D towards E, or move the two slides farther apart. If a better control of the current is wanted increase the current to about the desired value by moving but one slide and make final adjustment by sliding the second contact forward or back.

Two such rheostats have been made in Nela Research Laboratories and used regularly for a year or more and found convenient and satisfactory. It is often convenient to control a current of fifty to sixty amperes with a rheostat originally constructed to carry but thirty.

CLEVELAND, OHIO,
March, 1922.

An Interesting Case of Mechanical Disintegration Caused by Positive Ions. H. P. WARAN. (*Phil. Mag.*, January, 1922.)—The capillary of an ordinary Pluecker tube, with a pressure of a few mm., was placed between the conical poles of an electromagnet. When the tube was traversed by an unrectified current from an induction coil, the electron stream was deflected first against one side wall of the glass and then against the other. When an especially strong current passed, it took only a few seconds for a gray patch to develop on the glass "indicating a corrosion of the glass under the sand-blast action of the ions." A quite definite fish-bone pattern is produced, but the arrangements on the two sides of the glass tube are reversed. "There can be little doubt that this grooving of the glass was effected by the bombardment of the massive positive ions which travel in opposite directions in the two streams causing grooves that converge in opposite directions."

G. F. S.

NOTES FROM THE RESEARCH LABORATORY EASTMAN KODAK COMPANY.*

THE ELASTIC PROPERTIES OF GELATIN JELLIES.[1]

By S. E. Sheppard and S. S. Sweet.

THIS is a continuation of work previously reported dealing with the determination of the modulus of elasticity of gelatin jellies of various concentrations. The authors give measurements of the rigidity of gelatin jellies showing that the jellies follow Hooke's law nearly up to the breaking point. The relation of the modulus of elasticity to the concentration of gelatin is discussed. It is found that a function of the type $D = k\ c^n$ is valid for a certain range, but that the constants K and n may vary from one grade of gelatin to another. The influence of acidity and alkalinity on the elasticity has been followed quantitatively. p_H measurements show that the observed variations in the elasticity are not a simple function of the actual hydrogen ion concentration. The influence of alcohol and glycerol in different concentrations on the coefficient of rigidity have been measured.

THE EFFICIENCY OF THE BUCKY DIAPHRAGM PRINCIPLE.[2]

By R. B. Wilsey.

USING a six-inch depth of water as the scattering material, the efficiency of the Bucky diaphragm in removing scattered x-radiation has been measured for a variety of widths and depths of slit. The intensity of diffuse radiation was found to be a function of the ratio of slit width to slit depth, not depending on the actual size of the slit. The Bucky diaphragm was found to be highly efficient, it being easily possible to remove 80 to 90 per cent. of the scattered radiation. The wood filler used to support the lead strips has only a slight effect upon the efficiency of

* Communicated by the Director.

[1] Communication No. 108 from the Research Laboratory, Eastman Kodak Company, and published in *J. Amer. Chem. Soc.*, March, 1921, p. 539.

[2] Communication No. 129 from the Research Laboratory, Eastman Kodak Company, and published in *Amer. J. Röntg.*, **9**, 1, Jan., 1922, pp. 58–67.

the diaphragm; for small sizes of slit, its influence is practically negligible.

The definition obtainable with the Bucky diaphragm depends chiefly on the distance between the subject röntgenographed and the film; by making this distance sufficiently small (⅜ inch or less), the Bucky diaphragm can be made to give a considerable improvement in definition over the ordinary technic, and can be used with advantage in röntgenographing thicknesses as small as four inches.

The crossed grid of the original Bucky type (resembling a honeycomb) gives very little advantage over the Potter type of grid with the same depth of slit; it is concluded that the best practical improvement of the Bucky diaphragm lies in pushing the Potter type of grid to the limit of its effectiveness, that is, by making the grid as thin and as fine meshed as possible.

Characteristic X-rays from Carbon and Boron. A. L. HUGHES. (*Phil. Mag.*, January, 1922.)—There is a considerable gap between the longest X-ray wave-lengths and the shortest lengths in the ultra-violet. Unless very recent progress has been made, the longest X-rays, a K line from sodium and an L line from zinc, had the length of about 12 Ångstrom units, while the shortest line in the ultra-violet yet photographed is 202 units in wave-length. The gap is consequently a little over four octaves in extent. "There is no reason to believe that X-rays of still longer wave-length cannot be produced, but no crystal has been found, or is likely to be found, with spacings between its planes sufficiently large to measure appreciably longer wave-lengths. It is unlikely, therefore, that the spectrum can be extended more than a few Ångstrom units by the method of crystal analysis." A different method must therefore be used. Building on the experimental foundation laid by Beatty and others, the experimenter directed a stream of electrons upon a boron target, let the resulting X-rays fall on a metal plate that gave off photo-electrons under the excitation and measured this photo-electric current. By increasing step by step the energy of the incident electrons a point is reached when the characteristic radiation of the boron begins to be emitted. This condition is recognized by a marked increase in the photo-electric current. There is a known relation existing between the potential accelerating the electrons and the wave-length of the characteristic radiation developed. From this the latter is calculated, and is found to be 83.5 units, while for carbon the length of 57.5 units is obtained. This is indeed a notable extension of the X-ray spectrum.

G. F. S.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

THE CHEMICAL COMPOSITION OF CORN OIL.[1]

By Walter F. Baughman and George S. Jamieson.

[ABSTRACT.]

THE oil used for this investigation was expressed from dry process corn germs by an oil expeller. The following physical and chemical characteristics were determined:

Specific gravity 25/25–C	0.9185
Refractive index 20° C	1.4717
Iodine number (Hanus)	117.2
Saponification value	187.3
Unsaponifiable matter (per cent.)	1.7
Acid value	2.5
Acetyl value	10.0
Saturated acids (per cent.)	11.2
Unsaturated acids (per cent.)	82.5

The chemical composition of the corn oil was as follows:

		Per cent.
Glycerides of	Oleic acid	45.4
	Linolic acid	40.9
	Palmitic acid	7.7
	Stearic acid	3.5
	Arachidic acid	0.4
	Lignoceric acid	0.2
	Unsaponifiable	1.7
		99.8

It is interesting to note that Hehner and Mitchell (*Analyst*, 21 (1896) : 328) could not detect stearic acid in corn oil, while Lewkowitsch quotes Vulte and Gibson as authority for the statement that the saturated acids of corn oil consist of palmitic, stearic, and arachidic acids. The results of the Bureau's investigation confirm Gibson's statement and show in addition the presence of a small amount of lignoceric acid.

* Communicated by the Chief of the Bureau.

[1] Published in *J. Amer. Chem. Soc.*, **43** (1921) : 2696.

THE SOURCES AND CHARACTERISTICS OF THE BACTERIA IN DECOMPOSING SALMON.[1]

By Albert C. Hunter.

[ABSTRACT.]

IN studying the distribution of the bacteria concerned in the decomposition of salmon, 316 cultures were collected from sea-water, from decomposing salmon and from salmon canneries throughout southeastern Alaska. After discarding those cultures which were soon recognized as duplicate, 85 cultures were kept for further study. One of these cultures was actinomyces, one was a pink yeast, and four were white yeasts. Of the remaining 79 cultures, 72 were rod-shaped organisms without spores, 3 were spore-forming rods, and 4 were streptococci.

While no attempt was made to specifically identify many of the cultures, six were identified as *Bact. cloacæ,* three as *Bact. aerogenes,* two as *Bact. coli,* one as *Bact. communior,* and four as *Ps. fluorescens.* The majority of the bacteria collected apparently belong to a large group of non-fermenting soil and water bacteria.

Of the original 316 cultures, 71 were *Ps. fluorescens,* 27 were *Bact. cloacæ,* and 12 were cultures of an unidentified flesh-colored organism represented as Culture 360. The predominance of these three organisms, when considered in connection with their decomposing action on salmon, indicates that they play an important part in the decomposition of the salmon.

Eighty per cent. of the bacteria collected from sea-water were also found in decomposing salmon, in the canneries, or in both. Approximately 52 per cent. of the salmon cultures were also found in sea-water or in the canneries, and about 34 per cent. of the cultures from the Alaskan canneries were also obtained from other sources.

The results of this investigation confirm the statement previously made that the bacteria concerned in the decomposition of salmon are those forms which are regularly found in the sea-water from which the salmon are taken, and that the decomposition of salmon is not due to bacteria which contaminate the salmon within the cannery.

[1] Published in *J. Bact.,* 7 (1922): 85.

VIABILITY OF THE COLON-TYPHOID GROUP IN CARBONATED WATER AND CARBONATED BEVERAGES.[1]

By S. A. Koser and W. W. Skinner.

[ABSTRACT.]

Carbonation exerts a distinctly harmful effect upon the members of the colon-typhoid group, the period of viability of which is much shorter in carbonated water than in plain tap water. The destructive effect of the carbon dioxide is especially marked at room temperature (19 to 23° C.); it is less marked at 1° C.

The organisms may persist for a slightly longer period in a "non-acid" beverage than in carbonated water. In beverages containing 0.094 per cent. or more of citric or lactic acids, the death-rate is very rapid, being due apparently to the effect of these two acids.

Bact. typhosum and *Bact. paratyphosum B* are more readily destroyed by carbon dioxide than is *Bact. coli.*

The spore forms of a common aerobe, *B. mesentericus,* and of a common anaerobe, *Clost. sporogenes,* proved to be quite resistant to carbonation, surviving for one month at room temperature with no apparent diminution in numbers.

New Measurements of Stellar Radiation. W. W. Coblentz. (*Astrophys. J.*, Jan., 1922.)—These measurements were carried out at the Lowell Observatory, Flagstaff, Arizona, with the use of a vacuum thermo-couple and confirm certain conclusions derived from observations made at the lower altitude of the Lick Observatory. If a red star and a blue star appear to be of the same magnitude, the red star emits from 2.5 to 3 times as much total radiation as the blue one. If three stars, respectively blue, yellow and red, emit the same amount of total radiation, then the blue star emits twice as much visible radiation as the yellow star and three times as much as the red one.

By means of transmission screens the distribution of energy in the spectra of 16 stars was determined. The percentage of stellar energy transmitted through a layer of water one cm. thick was measured. These are some of the results: Rigel, 63; Castor, 82; Sirius, 65; Capella, 57; Aldebaran, 42; Betelgeuse, 34. The blue stars emit a smaller amount of infra-red radiation than do red stars of the same apparent magnitude.

G. F. S.

---

[1] Published in *J. Bact.*, 7 (1922): 111-121.

At the meeting of the French Physical Society on December 16, 1921, A. Perard reported on progress made with the quartz standards of length recommended by the International Committee on Weights and Measures. These are square prisms, 25 mm. on a side with the edges parallel to the crystallographic axis. The length embodied by each prism is not the distance between two cross lines but the distance between the two accurate and parallel planes forming the ends. Two interference methods based on Michelson's arrangement are used to measure the length. It is not necessary to silver the ends of the prism. By one of these methods prisms of the several lengths, 1, 2, 4, 10 and 20 mm., have been measured. In the discussion which followed the paper Professor Fabry directed attention to the difficulty of obtaining satisfactory sources of monochromatic light for metrological purposes. Commercial mercury vapor lamps are durable and convenient, but unfortunately each line has satellites. The cadmium tube to produce the red X-ray in the wave-length of which standard lengths are now expressed is not only fragile but has to be made in the laboratory. Neon gives light that will prove of use in accurate measurements and its commercial applications make it easy to get. The rays of krypton are exceptionally sharp, but this gas is hard to obtain in France. The construction of tubes filled with this gas would have little or no practical value, but, on the other hand, would be of distinct scientific advantage.

G. F. S.

Radium for England. (*Science*, Oct. 21, 1921.)—Frederick Soddy, professor of chemistry in Oxford, visited the Joachimsthal mines in Czecho-Slovakia and inspected them thoroughly, seeing also the processes for extracting radium from the pitchblende. On his return he brought with him to England two grams of radium, valued at £70,000. The transportation of so large a mass of this substance was not an easy matter in view of the constant emission of particles at enormous velocities. The radium was divided up between nine glass phials placed within a case of lead three inches thick and Doctor Soddy travelled as a King's Messenger. Upon his arrival his precious burden was deposited in the Foreign Office. The owner of the radium, The Imperial and Foreign Corporation of London, has an agreement with the Czecho-Slovakian government by which it gets the loan of the radium output of the mines for a period of fifteen years, less an amount reserved for public use. The state will continue to work the mines.

The Corporation expects to make use of its recent importation thus: "The radium will be lent freely for hospital purposes, and rented out to private practitioners. It will also be used for the production and sale of radio-active water in bottles, for use at radio-sanatoria, the production and sale of radio-active fertilizers, and for its by-products, such as polonium." G. F. S.

NOTES FROM THE U. S. BUREAU OF MINES.*

PERMEABILITY OF REFRACTORIES TO AIR.

By H. W. Douda.

THE porosity of a refractory has generally been used as an indication of the suitability of the raw material for use in making refractories. Permeability to air has now been utilized as a measure of the same property. Fire clay, bauxite, silica, magnesite, zirkite, graphite, and insulating bricks were tested.

A known volume of air was passed through a cylindrical section of brick, by displacement with water and the pressure and time were noted at each drop of 50 c.c.

Permeability may be expressed as the number of cubic centimetres of air passing through a mass of refractory, one square centimetre in cross-section by one centimetre long, in one second under a pressure of one centimetre of water.

Permeability is not directly proportional to porosity but is more dependent on pore structure, and to various degrees on temperature of burning, size of grain and method of manufacture. It has been more fully discussed in a paper recently presented by the author before the American Ceramic Society.

THE PROPERTIES OF SOME CLAY-LIKE MINERALS OF THE BENTONITE TYPE.

By H. G. Schurecht and H. W. Douda.

BENTONITES are probably aggregates of alkaline hydrated silica and kaolinite in varying proportions. They, as is indicated in a more complete discussion of them by the authors, before the American Ceramic Society, are characterized by the following properties: Conchoidal fracture; an index of refraction between 1.48 and 1.54; high water of plasticity and high volume drying shrinkage, varying from those of highly plastic clays to 114.61 and 195.8 per cent., respectively; and a high content of alkali plus alkaline earth, usually more than 5 per cent. When added

* Communicated by the Director.

to clays they increase the bonding power to a remarkable extent. In firing they vitrify below 1000° C., soften at cones 1 to 14, and burn to a buff to brown color. Because of this color they can only be used in small amounts in whiteware.

It is possible by adding quartz and bentonite to certain fire clays to produce clays approaching the Gross Almerode and Arkansas glass pot clays in properties.

PROPERTIES OF KANSAS CRUDES.

By E. W. Dean.

THE Bureau has recently completed a survey of crude oils from the Kansas district, which is part of a general survey of crude oils from all the producing fields of the United States. Work on samples from the Eastern fields, Rocky Mountain districts, and the fields of northern Texas, northern Louisiana, and Arkansas, had been previously completed and the results published.

The distillations of the Kansas crudes indicate a narrow gravity range, most of them falling between 27° and 37° B, with a minimum of 19.4° and a maximum of 43.5° B. Sulphur content varied from 0.12 to 0.66 per cent., most of the samples falling between 0.20 and 0.40 per cent. The gasoline-naphtha content ranged from 10 to 30 per cent., averaging 22.3 per cent. The gasoline and naphtha were grouped together in making the distillations, so that the figures are somewhat more favorable than are generally attributed to Kansas crudes. Further details are given in a report recently published by the Bureau of Mines in mimeograph form.

USE OF LOW-PRESSURE GAS IN OIL FIELD BURNERS.

By M. P. Youker.

LARGE quantities of low-pressure gas are wasted into the air in vicinities where drilling operations are being carried on by the use of oil or high-pressure gas. If the low-pressure gas could be used, marketable fuels would thus be conserved, and frequently the entire cost of fuel for drilling saved to the operator. The Bureau of Mines, in coöperation with the Osage Oil and Gas Lessees Association and the Osage Indian Agency, has conducted

experiments to determine whether low-pressure gas can be used to advantage in oil field boilers to generate steam for drilling and what types of burners would be best for this purpose.

The steam consumption of the ordinary drilling equipment was determined in the field, after which a test boiler was installed at the petroleum experiment station of the Bureau, at Bartlesville, Oklahoma, and various types of low-pressure gas burners were tested under conditions approximating actual field loads. Of 11 burners tested, 9 were found to have sufficient capacity to operate a standard rig drilling to depths of 2800 feet, at gas pressures below 5 pounds at the burner, and some of the burners required less than one pound gas pressure. Further details of the results will be found in the complete report of this investigation, printed as part of the Year-book of the Mid-Continent Oil and Gas Association, Tulsa, Oklahoma.

Fall of Potential and Vertical Conduction Currents of Electricity in the Free Atmosphere. E. Everling and A. Wigand. (*Ann. d. Physik*, No. 20, 1921.)—It has been known for a long time that the atmosphere has higher potential than the earth itself. Accordingly in coming down through the air there is a fall of potential. Moreover the air has a certain conductivity. Then since it can conduct, and since there is a fall of potential downward along the vertical, it follows that currents flow through it downward toward the earth. From quite a different point of view, L. A. Bauer has established the existence of such currents by the formation of line integrals.

The two German meteorologists present the results of two balloon flights reaching up to almost 9 km. (5.5 miles). They found that the fall of potential, which has a value of about 27 volts per metre at a height of 2.5 km. above the earth, at first diminishes quite rapidly with height, then more slowly, and that it seems to have a value of no more than 4 volts per metre when an elevation of 9 km. is attained.

The conductivity of the air, on the other hand, is much less near the earth than at greater altitudes. At 3.5 km. it is nine or ten times as great as it is a few metres above the earth's surface. By combining the results of conductivity with those for the fall of potential the vertical earth currents were calculated. There is not so much change in these with altitude, but there is a recognizable decrease as the elevation grows greater.

The authors deserve credit for their scientific enthusiasm which led them to perform such experiments in the car of a balloon where each was cramped for space and where the usual operation of their lungs had to be artificially supplemented. G. F. S.

Measurement of the Thomson Effect at Low Temperatures. G. BORELIUS and F. GUNNESON. (*Ann. d. Physik.*, No. 14, 1921.)—If the middle point of a metal wire be kept at one temperature, while the two ends are maintained at some different temperature alike for both, then with symmetrical conditions two points of the wire at the same distance from the middle would have the same temperature. Let now an electric current flow from one end of the wire to the other. In one-half of the wire it goes uphill as regards temperature and in the other half downhill. The two points which previously had the same temperature now are found to have different temperatures. One point has grown warmer while the other is cooler. Lord Kelvin inferred the existence of this phenomenon and confirmed his conclusions by experiment. Hence the designation "Thomson Effect." The effect is reversed in sign when the current is reversed and at a given temperature the direction is dependent upon the metal of the wire.

The two investigators in the University of Lund have examined copper, silver, gold, zinc, cadmium, tin and lead from the temperature of liquid air to that of boiling water. In the cases of copper, silver, cadmium and tin there is a temperature within the specified range at which the direction of the effect reverses itself, that is, if the current flows toward parts of the wire at higher temperatures and in so doing raises the temperature of the wire, then upon elevating sufficiently the temperature of the wire the current will no longer raise but will on the contrary lower the temperature. No such change was observed with gold, zinc, and lead. When curves are plotted connecting temperature with volts per degree for copper, silver and gold the forms are similar as might be expected from the relations of these metals in the Periodic System. The results are given in micro-volts (millionths of a volt) per degree. Cadmium displays the greatest change with temperature—0 at 150° abs. to 9.8 at 380° abs. Lead is very conservative in its changes in comparison with cadmium.

G. F. S.

Encouragement of Research on Glass.—With a view of securing additional information concerning the chemistry and physics of glass, a Committee of the American Ceramic Society has made arrangements for providing investigators with samples of desired composition and form. These will be supplied without charge, the only conditions being that the recipients shall proceed with investigations and furnish the results for publication. The following are the members of the Committee, to any one of whom the application for samples may be made: E. C. Sullivan, Corning Glass Works, Corning, New York; E. W. Washburn, University of Illinois, Urbana, Illinois, and R. B. Sosman, Geophysical Laboratory, Washington, D. C.

H. L.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, March 15, 1922.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 15, 1922.

DR. WALTON CLARK, President of the Institute, *in the Chair.*

The Board of Managers submitted its report. The report recorded the election to membership of:

J. L. Crenshaw, Ph.D.,
Associate Professor of Physical Chemistry,
Swarthmore College,
Swarthmore, Pennsylvania.

Isaac H. Francis, M E.,
Consulting Mechanical Engineer,
Otis Building,
Philadelphia, Pennsylvania.

D. H. Kabakjian, Ph.D.,
Assistant Professor of Physics,
University of Pennsylvania,
Philadelphia, Pennsylvania.

Theodore S. Rowland, A.B.,
Head of Science Department.
Northeast High School,
Philadelphia, Pennsylvania.

Alexander S. Gross, D.D.S., Phar.D.
Newton,
Kansas.

Walter F. Graham, B.S.,
Metallurgist,
Henry Souther Engineering Co.
Hartford, Connecticut.

E. B. Tuttle, E.E.,
Engineer of Transmission and Protection,
Bell Telephone Company of Pennsylvania,
Philadelphia, Pennsylvania.

Mr. Charles J. Ramsburg, Vice-president,
The Koppers Company,
Pittsburgh, Pennsylvania.

Augustus Trowbridge, Ph.D.,
Professor of Physics
Princeton University,
Princeton, New Jersey.;

lectures before the Sections by

Hugh S. Taylor, D.Sc.,
Associate Professor of Physical Chemistry,
Princeton University,
Princeton, New Jersey.

on "Catalysis and Catalytic Agents in Chemical Processes"; by

Colonel E. Lester Jones, A.M., Director,
U. S. Coast and Geodetic Survey,
Washington, District of Columbia.

on "Surveying from the Air";

lecture before the Stated Meeting February 15, 1922, by

L. J. Briggs, M.S., Ph.D.,
Chief of Engineering Physics Division,
Bureau of Standards,
Washington, District of Columbia.

on "Resistance of the Air";

a series of lectures on the afternoons of March 6th to 10th, inclusive, by

F. W. Aston, F.R.S., Fellow of Trinity College,
Cambridge,
England.

on "Atomic Weights and Isotopes";

and additions to the library by gift, 27 volumes and 102 pamphlets, by purchase, 15 volumes and by binding 76 volumes.

A report of progress was presented by the Committee on Science and the Arts.

The President then announced that the Philadelphia Section of the American Institute of Electrical Engineers was meeting jointly with the Institute and requested Mr. P. H. Chase, Chairman of the Philadelphia Section, to preside during the reading of the paper and its discussion. Dr. M. deKay Thompson, Associate Professor of Electrochemistry, Massachusetts Institute of Technology, Cambridge, Massachusetts, then presented the paper of the evening on "Recent Progress in Applied Electrochemistry." An account was given of the recent progress in the different branches of electroplating, batteries, and the manufacture of numerous substances by electrolysis and electrothermic means. The subject was illustrated by lantern slides.

A unanimous vote of thanks was extended to Doctor Thompson for his interesting paper.

Adjourned.

R. B. OWENS.
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, March 1, 1922.)

HALL OF THE INSTITUTE,
PHILADELPHIA, March 1, 1922.

DR. JAMES BARNES *in the Chair.*

The following reports were presented for first reading:

No. 2783: Interlocking Tooth Saw.
No. 2787: Literature.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, February 9, 1922, at 8 o'clock. The minutes of the previous meeting were read and approved.

L. J. Henderson, M.D., Professor of Biological Chemistry in Harvard University, Cambridge, Massachusetts, delivered an illustrated lecture on "Applications of Physical Chemistry to the Physiology of Breathing." The respiratory changes in the blood were described; and an account was given of the various factors which control the transport of oxygen and carbon dioxide in the blood stream and produce an extremely complex chemical equilibrium.

The communication was discussed by Dr. Carl Hering, Doctor Henderson, and others. A vote of thanks was extended to Doctor Henderson; and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, February 23rd, at eight o'clock, with Dr. R. B. Owens in the Chair. The minutes of the previous meeting were approved.

Hugh S. Taylor, Sc.D., Associate Professor of Physical Chemistry in Princeton University, Princeton, New Jersey, delivered a lecture on "Catalysis and Catalytic Agents in Chemical Processes." The following subjects were discussed: "The General Features and the Theories of Catalysis and Catalytic Agents," "The Principles and Methods of Research in Problems of Catalysis," "The Form of the Catalyst, Poisons, Promoters," "The Technical Applications of Catalysis." The lecture was illustrated with specimens and with lantern slides. After a lengthy discussion of the communication, a vote of thanks was extended to Doctor Taylor, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

ELECTION TO MEMBERSHIP.

(Stated Meeting, Board of Managers, March 8, 1922.)

RESIDENT MEMBERSHIP.

DR. J. L. CRENSHAW, Bryn Mawr College, Bryn Mawr, Pennsylvania.

MR. ISAAC H. FRANCIS, Otis Building, Philadelphia, Pennsylvania.

DR. D. H. KABAKJIAN, Department of Physics, University of Pennsylvania, Philadelphia, Pennsylvania.

MR. THOS. S. ROWLAND, 6311 N. Camac Street, Philadelphia, Pennsylvania.

MR. E. B. TUTTLE, Bell Telephone Company, 261 N. Broad Street, Philadelphia, Pennsylvania.

NON-RESIDENT.

MR. WALTER FRANKLIN GRAHAM, 11 Laurel Street, Hartford, Connecticut.
DR. A. S. GROSS, 508½ Main Street, Newton, Kansas.
MR. C. J. RAMSBURG, Koppers Company, Pittsburgh, Pennsylvania.
PROF. AUGUSTUS TROWBRIDGE, Princeton University, Princeton, New Jersey.

CHANGES OF ADDRESS.

COLONEL P. JUNKERSFELD, McClellan & Junkersfeld, Inc., 45 William Street, New York City, New York.
DR. RUDOLPH HERING, 550 W. 157th Street, New York City, New York.
MR. I. N. KNAPP, 504 Aspen Street, N. W., Tacoma Park, Washington, District of Columbia.
MR. HOWARD C. SLATER, Ridley Park, Pennsylvania.
DR. LESLIE D. SMITH, 406 Rutland Courts, 1725—17th Street, N. W., Washington, District of Columbia.
MR. J. T. WALLIS, Chief of Motive Power, Pennsylvania System, Broad Street Station, Philadelphia, Pennsylvania.
MR. JOHN WIEGAND, 2020 N. Marshall Street, Philadelphia, Pennsylvania.

NECROLOGY.

Charles Baskerville was born on July 18, 1870, at Deer Brook, Mississippi, and died on January 28, 1922, at New York City. His early training was obtained in the Universities of Mississippi, Virginia, Vanderbilt and North Carolina, receiving from the latter the degree of Bachelor of Science, in 1892. The University of Berlin conferred upon him the degree of Doctor of Philosophy in 1893, also the University of North Carolina in 1894. He was instructor in Chemistry, 1891–1894, at the latter institution; Assistant Professor of Chemistry, 1895–1898; Associate Professor of Chemistry, 1898 to 1900, and Professor of Chemistry, 1900 to 1904. In 1904 he accepted the Professorship of Chemistry and the Directorship of the Chemical Laboratories of the College of the City of New York, which positions he held until the time of his death. He was a member of the leading chemical societies of this country and Europe and was also connected with many of the other technical and scientific organizations. In addition to nearly two hundred papers which he published in the scientific and technical press since 1893, the following are the more important of his books:

"School Chemistry and Key," 1898.
"Radium and Radioactive Substances. Their Application Especially to Medicine," 1905.
"General Inorganic Chemistry," 1909.
"Laboratory Exercises to be Used with General Inorganic Chemistry" (with R. M. Curtis), 1909.
"Course in Qualitative Chemical Analysis" (with L. J. Curtman), 1910.
"Progressive Problems in General Chemistry" (with W. L. Estabrooke), 1910.
"Anæsthesia" (with J. T. Gwathmey), 1914.

He was also editor of "Municipal Chemistry," published in 1911.

Doctor Baskerville became a member of The Franklin Institute on July 2, 1904. He was awarded the Institute's Edward Longstreth Medal in 1912. Few American chemists were more widely known for their contributions both in the fields of pure and applied science and as a successful teacher. He was possessed of a peculiar personal charm that will always be remembered by those, and there were many, fortunate enough to know him.

Dr. William Frear, whose death occurred at State College, Pennsylvania, on January 7, 1922, was born at Reading, Pennsylvania, in 1860. His father was a clergyman. He was educated at Bucknell University, receiving therefrom in 1881 the degree of Bachelor of Arts. In 1883 he received his doctorate from Wesleyan University of Illinois. He began teaching as soon as he had finished his course at Bucknell, and was for several years associated with the Natural Science Department of that Institution. From there he went to the Department of Agriculture of the United States, serving for two years as an assistant chemist. This gave him the definite direction for his life work, and in 1885 he was appointed assistant professor of Chemistry at Pennsylvania State College. Two years later he became full professor, serving until 1908. The extensive development of experiment station work and the concentration of such at the State College caused his transfer to research work and to the administration of the fertilizer control which was established under the State Law. In this field he was active for many years, during which he took part in the work of the State Board of Agriculture.

The control of the food supplies of Pennsylvania was first undertaken by the State Board of Agriculture, and much of the work was done in connection with State College, so that Doctor Frear was actively concerned with this line. Later the organization of the Association of Official Agricultural Chemists brought him into direct relation with the development and investigations of the methods of analysis, intended to secure accuracy and uniformity in the examination of foods. Subsequently, the Pennsylvania food control was placed under a definite bureau with which Doctor Frear was associated from 1895 on.

Doctor Frear devoted himself with great assiduity to the fields to which he was assigned, and enriched agricultural and food chemistry with many important researches among which are studies of the culture of tobacco, of the composition of commercial vinegars and breakfast foods, effects of lime in fertilizers, digestibility of cattle foods, proximate composition of forage plants, soil acidity and the composition of Pennsylvania limestones. He was a member of many societies for the promotion of knowledge of chemistry and agriculture, including the Deutsche Chemische Gesellschaft.

Personally, Doctor Frear was an agreeable, companionable gentleman, ever ready to advise upon matters with which he was familiar, and very earnest in the pursuit of the problems which lay before him. During his too short life, he enriched chemistry as applied to agriculture and to food control with many valuable discoveries, and his loss will be deeply felt in these fields.

HENRY LEFFMANN.

John C. Pennie was born in Albany, New York, on August 29, 1858, and died in New York City on December 23, 1921. He was educated in the public schools of his native city, and in 1874 entered Union College, from which he was graduated in June, 1877, with the degree of Civil Engineer and Bachelor of Arts. He then attended the Albany Law School where he obtained the degree of Bachelor of Laws and concluded his legal studies at the Universities of Breslau and Göttingen. On his return to this country Mr. Pennie was admitted to the bar of the State of New York, but decided to devote himself to patent practice and accepted a position as assistant examiner in the Patent Office. Two years later he resigned his position and entered upon the practice of law, removing his office in 1904 to New York City, where he has since been active. In 1919 he was elected as the advisor on Patent Matters of the American Commission to Negotiate Peace and spent six months in Paris. For his services in this connection he was made a Commander of the Crown by King Albert of Belgium.

Mr. Pennie became a member of The Franklin Institute on July 3, 1889.

William Henry Richmond was born at Marlborough, Hartford County, Connecticut, on October 23, 1821, and died at Daytona, Florida, on March 14, 1922. Mr. Richmond was educated in the Marlborough and Middle Haddam, Connecticut, public and private schools. He spent from his thirteenth to his sixteenth years in business, but resumed his studies in 1837 continuing to 1842. In 1860 he first began the mining of coal in Blakeley Township near Scranton, Pennsylvania, and erected one of the first coal breakers on the Delaware and Hudson Canal.

Mr. Richmond was a director in a number of banking concerns and was a member of the leading technical societies. He became a member of The Franklin Institute in December, 1912.

Mr. Wm. C. Carnell, 1141 Arrott Street, Frankford, Philadelphia, Pennsylvania.

Mr. Frank H. Clement, Land Title Building, Philadelphia, Pennsylvania.

LIBRARY NOTES.

PURCHASES.

American Institute of Chemical Engineers, *Transactions 1918.* 1920.
BOLTON, L.—Introduction to the Theory of Relativity. No date.
CAMPBELL, NORMAN R.—Physics of the Elements. 1920.
GAGE, SIMON HENRY.—The Microscope. 1920.
HALE, HARRISON.—American Chemistry. 1921.
KIDDER, FRANK E.—Architects' and Builders' Handbook. 1921.
MARTIN, MARCUS J.—Electrical Transmission of Photographs. 1921.
MERCER, J. E.—Alchemy, its Science and Romance. 1921.
Photograms of the Year. 1921.

SCOTT-TAGGART, JOHN.—Thermionic Tubes in Radio-telegraphy and Telephony. 1921.

WALKER, MILES.—Diagnosing Troubles in Electrical Machines. 1921.

ZIPSER, JULIUS.—Textile Raw Materials and Their Conversion into Yarns. 1921.

GIFTS.

Adamson, Daniel, and Company, Ltd., Cheap Power and Compressed Air. Dukinfield, England, no date. (From the Company.)

Alfred College, Catalogue 1921–1922. Alfred, New York, 1921. (From the College.)

Allen, Edgar, and Company, Ltd., Saw Service. Sheffield, England, 1921. (From the Company.)

Allen-Liversidge, Limited, Portable Acetylene Lamps and Country House Lighting. London, England, no date. (From the Company.)

American Institute of Mining and Metallurgical Engineers, Transactions, vol. lxv. New York City, New York, 1921. (From the Institute.)

American Society of Mechanical Engineers, Year Book, 1922. New York City, New York, 1921. (From the Society.)

Amherst College, Catalogue 1921–1922. Amherst, Massachusetts, 1921. (From the College.)

Armature Coil Equipment Company, Superior Coil Winding Machine. Cleveland, Ohio, no date. (From the Company.)

Armour and Company, Catalogue for 1922. Chicago, Illinois, 1921. (From the Company.)

Beldam Packing and Rubber Company, Limited, Catalogue of Engine Packings, etc. Brentford, Middlesex, England, 1921. (From the Company.)

Blackman Export Company, Limited, Air Heaters and Washers. London, England, 1921. (From the Company.)

Blackstone and Company, Limited, Publication 243 on Oil Engines. Stamford, England, 1921. (From the Company.)

Brett Patent Lifter Company, Limited, General Catalogue of Brett Drop-forging Equipments. Coventry, England, 1921. (From the Company.)

Bristol Company, Preliminary Catalogue No. 1501. Waterbury, Connecticut, 1921. (From the Company.)

Bryant Electric Company, Superior Wiring Devices. Bridgeport, Connecticut, 1920. (From the Company.)

Canadian Car and Foundry Company, Limited, Bulletins 11, 12, 13, 21, 22, 23, 24, 25, 26, 31, 41, 42 and 43. Montreal, Canada, no date. (From the Company.)

Carter Bloxonend Flooring Company, Pamphlet of Bloxonend Flooring. New York City, New York, no date. (From the Company.)

Central Scientific Company, Catalogue E. Chicago, Illinois, 1920. (From the Company.)

Cole, Marchent and Morley, Ltd., Catalogue of Coal Consumption. Bradford, Yorks, England, 1921. (From the Company.)

Colorado School of Mines, Catalogue. Golden, Colorado, 1922. (From the School.)

Columbia University, Summer Session Announcement, 1922. New York City, New York, 1922. (From the University.)

Cooke, T., and Sons, Limited, Direct Reading Tacheometer and Surveying and Other Scientific Instruments. London, England, no date. (From the Company.)

Crafts, Arthur A., and Company, Diamonds Used in Tools. Boston, Massachusetts, no date. (From the Company.)

Dartmouth College, Catalogue 1921–1922. Hanover, New Hampshire, 1921. (From the College.)

Direct Separator Company, Catalogue 19 of Steam and Oil Separators. Syracuse, New York, 1921. (From the Company.)

Donovan and Company, Safuse and Donlok Gears. Birmingham, England, 1921. (From the Company.)

Dorr Company, Testing that Pays Dividends. New York City, New York, no date. (From the Company.)

Duncan Stewart and Company, Limited, Catalogue of Billet, Plate and Slab Shears. Glasgow, Scotland, 1921. (From the Company.)

Dunham, C. A., Company, Bulletin 109 of Return Heating System. Chicago, Illinois, 1921. (From the Company.)

Dust Recovering and Conveying Company, Bulletins 502, 505, 506 and 1001. Cleveland, Ohio, 1921. (From the Company.)

Eastern Machine Screw Corporation, Die Heads. New Haven, Connecticut, 1921. (From the Corporation.)

Eck Dynamo and Motor Company, Bulletins 1300, 1600 and 1900. Belleville, New Jersey, 1921. (From the Company.)

Electric Storage Battery Company, Catalogue of Exide Batteries, Section SLP. Philadelphia, Pennsylvania, 1922. (From the Company.)

Esterline-Angus Company, Bulletins 122 and 222. Indianapolis, Indiana, 1921. (From the Company.)

Foster Instrument Company, Book 26 of Practical Pyrometers and Book 23 of Radiation Pyrometry. Letchworth, Herts, England, 1921. (From the Company.)

Goulds Manufacturing Company, Bulletin 123 of Goulds Pumps. Seneca Falls, New York, 1921. (From the Company.)

Gray, The G. A., Company, Gray Planers. Cincinnati, Ohio, 1921. (From the Company.)

Harbour Improvement and Mechanical Engineering Company, Limited, Cranes and Hoisting Machinery. London, England, 1921. (From the Company.)

Hardinge Company, Catalogue 12 of Quigley Fuel Systems. New York City, New York, 1922. (From the Company.)

Harvard College Astronomical Observatory, Annals, vol. 96. Cambridge, Massachusetts, 1921. (From the Observatory.)

Harvey, G. A., and Company, Limited, Catalogue of Chimneys. London, England, no date. (From the Company.)

Hayward Company, Hayward Buckets, Catalogue 43. New York City, New York, 1916. (From the Company.)

Higgs Brothers, Electric Motor Specification No. 7. Birmingham, England, 1921. (From the Company.)

Shannon, J. Jacob, and Company, Catalogue of Derricks, Engines and Equipment. Philadelphia, Pennsylvania, no date. (From the Company.)

Siemens Brothers and Company, Limited, Pamphlets A701, 702A, B705, 709A, A720 and 730A. Woolwich, England, 1921. (From the Company.)

Simon-Carves, Limited, Catalogue A.P. 3 and 4. Manchester, England, no date. (From the Company.)

Skinner Chuck Company, Skinner Chucks and Chucks and Their Uses. New Britain, Connecticut, 1920. (From the Company.)

Smith College, Catalogue 1921–1922. Northampton, Massachusetts, 1921. (From the College.)

Smith, Thomas, Stamping Works, Limited, Drop Forgings Plus Service. Coventry, England, no date. (From the Works.)

Spencer-Bonecourt, Limited, Modern Steam Generation. London, England, 1921. (From the Company.)

Steam Fittings Company, Limited, Automatic Temperature Regulation. West Drayton, England, 1921. (From the Company.)

Stebbins, E., Manufacturing Company, Catalogue of Brass Goods. Springfield, Massachusetts, 1922. (From the Company.)

Stockton and Bunn, Limited, Casehardening Compounds. London, England, no date. (From the Company.)

Sturtevant, B. F., Company, Bulletin 246, Generator Cooling Apparatus. Hyde Park, Boston, Massachusetts, 1921. (From the Company.)

Sullivan Machinery Company, Bulletins 70W, 71F and 71G. Chicago, Illinois, 1921. (From the Company.)

Taylor, J. Norman, and George W. Phillips, Nitrogen in the Arts and Industries. New York City, New York, 1921. (From Dr. Charles E. Munroe.)

Ternstedt Manufacturing Company, Catalogue 2 of Automobile Body Hardware. Detroit, Michigan, no date. (From the Company.)

Thor Electric Safety Lamp Company, Limited, Circular of "Thor" Miners' Lamp. Birmingham, England, no date. (From the Company.)

Tiffin Wagon Company, Motor Trucks and Street Sprinklers. Tiffin, Ohio, no date. (From the Company.)

Triplex Machine Tool Corporation, Catalogue No. 1 of Machine Tools. New York City, New York, no date. (From the Corporation.)

Union Mining Company, Catalogue H, Pertaining to Fire Brick. Baltimore, Maryland, 1921. (From the Company.)

United Fruit Company, Twenty-second Annual Report. Boston, Massachusetts, 1921. (From the Company.)

United States Electric Company, Bulletin No. 6. New London, Connecticut, no date. (From the Company.)

United States Geological Survey, Mines Report for 1919, and Bulletin 726G. Washington, District of Columbia, 1922. (From the Director.)

United States Naval Observatory, American Ephemeris and Nautical Almanac for 1924. Washington, District of Columbia, 1921. (From the Observatory.)

University of Maine, Catalogue 1921–1922. Orono, Maine, 1921. (From the University.)

University of Michigan, Catalogue 1920–1921. Ann Arbor, Michigan, 1921. (From the University.)

University of Missouri, Bulletin: The Problem of the St. Peter Sandstone. Rolla, Missouri, 1921. (From the University.)

University of Pennsylvania, Catalogue 1921–1922. Philadelphia, Pennsylvania, 1921. (From the University.)

University of Rochester, Catalogue 1921–1922. Rochester, New York, 1921. (From the University.)

V. and O. Press Company, Catalogue of Presses. Brooklyn, New York, 1921. (From the Company.)

Welch, W. M., Scientific Company, Catalogue of Direct Current Meters. Chicago, Illinois, no date. (From the Company.)

Wellman Smith Owen Engineering Corporation, Limited, Catalogue of Charging Machines. London, England, 1921. (From the Corporation.)

Western Australia Geological Survey, Bulletins 78, 79, 80 and 81. Perth, Western Australia, 1921. (From the Government Geologist.)

BOOK NOTICES.

COLLECTED PAPERS ON ACOUSTICS. By Wallace Clement Sabine, late Hollis Professor of Mathematics and Natural Philosophy in Harvard University. 279 pages, illustrations, plates, portrait, quarto. Cambridge, Harvard University Press, 1922. Price $4.00.

One of the blessings that the art of printing has conferred is that of providing in convenient form a permanent record of the work done by the scientific investigator. Such a record is of great value, not only to other investigators in the same field but to those who wish to know the steps by which the science or the art has reached its present development.

Professor Sabine's investigations in the field of applied acoustics, which are covered in this series of papers, were begun in 1895 when he was requested by the Corporation of Harvard University to propose changes in the lecture room of the Fogg Art Museum that would remedy defects in its acoustic properties. He spent two years in making these investigations and the result obtained did much to remove the chaotic condition of our knowledge of practical acoustics.

Professor Sabine recognized three requirements for good hearing in an auditorium that is itself good. The sound should be sufficiently loud, the simultaneous components of a complex sound should maintain their relative intensities and the successive sounds in rapid articulation should be clear, distinct and free from each other and from disturbing noises.

These, however, have to do with the production of sound and not with its transmission to the ear of the hearer. When this part of the problem is considered its requirements cannot be stated in such a simple form. If an audience room is built that is a replica of one known to have good acoustic qualities the builder cannot be sure that the hearing will be as good as it is in the original room. Some, apparently minor, detail has been omitted perhaps and this omission has entirely changed its character as an auditorium.

Professor Sabine set himself to the problem of finding out the effect of all that enters into the construction of an audience room upon its acoustic

qualities and in order to get measurable results he constructed models in which he could make changes and find the results of each.

One has but to read the table of contents of this book to see how thoroughly both the theoretical and practical side of sound have been covered in this group of papers extending from that on "Reverberation" published in the *American Achitect* for 1900 to that on the "Insulation of Sound" published in the *Bricklayer* for 1915.

Since the eleven papers included in the series are founded on lectures or papers delivered before scientific bodies over a series of years, a certain amount of repetition was to be expected.

Probably the most complete summary of Professor Sabine's Work is contained in the paper presented before The Franklin Institute in 1914 and printed in the JOURNAL OF THE INSTITUTE in 1915.

Professor Sabine's reputation in the field of acoustics is international as is evidenced by the lectures given by him at the Sorbonne in 1917. It is to be regretted these lectures were never prepared for publication in full.

GEO. A. HOADLEY.

THE VITAMINS. By H. C. Sherman, Professor of Food Chemistry, Columbia University, and S. L. Smith, Specialist in Biological and Food Chemistry in the United States Department of Agriculture. American Chemical Monograph Series. 234 pages, bibliography, index, illustrations and plates, 8vo. New York, The Chemical Catalog Company, 1922. Price, $4.00.

The literature of the vitamins has grown with great rapidity, and their uses have been exploited in both the scientific and popular fields. As might be expected, the charlatan has utilized the general interest to secure profit, and the columns of newspapers and non-scientific journals have been extensively occupied with statements of claims more or less exaggerated as to the value of certain foods. It is gratifying, therefore, to have in a compact form a selection of the trustworthy data. Though much of the information set forth is comparatively new, we find, as might be expected, some of the principles foreshadowed many years ago. From the useful and interesting historical note we learn that as early as 1720 it was pointed out that certain fresh vegetables and fruit juices would relieve scurvy which resisted all the usual means of medicine and surgery. The long sea voyages which began to be common after the discovery of America, and the ability to circumnavigate the globe caused scurvy to become a most serious source of disability, and during the eighteenth century, the British navy, which then controlled the seas, as it has done since, found this disease a source of high fatality. In 1804, the issue of a ration of lemon juice was made compulsory in this navy, and the disease became quite rare. The shorter voyages that are now common, owing to the introduction of steam, have rendered such precautions of less importance, but sailing vessels are still under the rule.

The general subject of the vitamins is too well known to chemists to require much statement here. The Historical Introduction gives the main items of discovery and investigation, by which the three forms now recognized have been indicated, that is the fat-soluble A, and water-soluble B and C. The term itself is somewhat of misnomer, apparently as at least some of the

substances are not amin derivatives. It will, doubtless, have to stand until the real structural formulas are discovered. A very large portion of the information regarding the three forms and their occurrence has been derived from feeding experiments on lower animals. These have been extremely numerous and the patience and care with which the work has been carried out merit high appreciation of all interested in food questions. One of the most important questions in practical food hygiene is the effect of heating milk. Control of the milk supply of a city is a very difficult problem. The country districts from which the supply comes are often far from being in good sanitary condition, and the methods of collecting, transporting and distributing are all sources of serious contamination. It has, therefore, seemed to municipal experts that sterilization or pasteurization will be satisfactory, as the greater part of the living organisms will be killed. It is now, however, generally admitted that sterilization is unwise, and it has been thought that equally good results as to cleaning the milk, without injuring its nutritive value appreciably, can be secured by heating to a lower temperature. For this reason the milk supplies of some cities are all pasteurized. Experiments, however, show that it is possible by such methods to injure materially the activity of the vitamin C, known as the anti-scorbutic vitamin. This exists in the watery portion of the milk, and may be injured by even pasteurization processes, so that children fed on such milk will fare but poorly. It is stated that the injury to the vitamin is partly due to oxidation; at least, pasteurization in a closed container does not produce as much injury as when the mass of milk is allowed to flow over a heated surface. Milk, by the way, as might be expected, contains all known vitamins. It appears from some clinical experiences that, so far as human beings are concerned, the growing animal is much more sensitive to lack of vitamins than the well-developed adult.

The work before us must be judged in two aspects: First, as to its merit as a member of the series, and second, as a contribution to the field to which it is devoted. In both aspects it deserves high praise. Its methods, form and general make-up maintain the character of the works of the series already published, and the authors have given full attention to the extensive literature as well as worked assiduously themselves in adding to the store of knowledge. The present available data on the question of vitamins, drawn so largely from experiments on the lower animals, will have to be subjected to the tests of wide clinical experience, before they can be regarded as fully established. In a review some years ago of a book by the senior author of the volume now in hand, the present reviewer postulated the query as to whether it was safe to attempt to reduce the human dietary to a mere matter of calories. The development of the vitamin theory seems to answer the question in the negative. All these problems are so complex that inferences must be considered tentative.

In the case of rickets, for instance, it has been shown that exposure to sunlight may overcome the effects of certain deficiencies of diet, and hence as stated by Hess, Unger and Pappenheimer in a recent publication (*J. Biol. Chem.*, vol. 50, 77) the illumination factor must always be taken into account. Sufficient has been said to show the excellence of the work of Messrs. Sherman and Smith. As a piece of book-making the volume is quite up to the best standards. It appears from a recent German review of one of the

books of this series that German scientists are not pleased at the method and earnestness with which Americans are building up an independent literature in these fields. To this the American can only say, "Let the stricken deer go weep."

HENRY LEFFMANN.

AN INTRODUCTION TO THE PHYSICS AND CHEMISTRY OF COLLOIDS. By Emil Hatschek. Fourth edition, entirely rewritten and enlarged. 12mo., 165 pages, contents, index and 30 illustrations. Philadelphia, P. Blakiston's Son and Company. Price, $2.25 net.

Hatschek's compact and interesting manual has been so long favorably known to those interested in physical chemistry, that this edition would seem to require no notice other than to announce its publication. The present volume is about double the size of the first edition, and records the present state of colloidal chemistry, the literature of which is growing at a very rapid rate. It seems occasionally to those not immersed in such studies, that the field has a sort of hypnotic influence over its votaries. They see colloids in every part of nature, from blue eyes to blue sky. The extensive work of one of the European authorities on the subject seems to indicate that he is prepared to hold the view that the primordial chaos was a colloid and the fiat of creation was a flocculation of it. The work now in hand can be recommended as a highly satisfactory introduction to the study of this important field. It has been largely rewritten, but some of the original matter remains. The illustration of ultramicroscope is the same as used in the first edition, and as there is little doubt that a fifth edition will be called for, it would be well to revise and extend somewhat this part of the book, presenting in some detail the later designs in apparatus for the observation of minute particles. The reference on page 14 to the fact that sand filters retain bacteria, although these organisms are much smaller than the interstices of the grains, is not opportune, as filtration engineers have shown that the retaining power of a slow sand filter is dependent on a growth of bacterial colonies, mostly in the upper layer of the sand, but partly deeper. It is this which acts as the retaining agent, and until such a filter is "ripe," that is, has formed this layer, it has low efficiency.

HENRY LEFFMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS. Report No. 123, Simplified Theory of the Magneto. By F. B. Silsbee, Bureau of Standards. 15 pages, illustrations, plate, quarto. Washington, Government Printing Office, 1922.

This paper contains part of the results of ignition investigations being made for the National Advisory Committee for Aeronautics at the Bureau of Standards, and describes a type of circuit which has been found useful for representing the action of the high-tension magneto. While this equivalent circuit is relatively simple, and consequently can be used as a basis for deriving definite mathematical formulas for induced voltages and similar quantities, it has been found experimentally to correspond quite closely in its performance with the highly complicated electrical circuits of an actual magneto. In the paper formulas are given for the voltage induced in the secondary under various conditions of operation, and a number of numerical examples are worked out showing the application of the equations to a variety of practical problems.

PUBLICATIONS RECEIVED.

Collected Papers on Acoustics, by Wallace Clement Sabine, late Hollis Professor of Mathematics and Natural Philosophy in Harvard University. 279 pages, illustrations, portrait, quarto. Cambridge (Mass.), *Harvard University Press,* 1922. Price, $4.00.

The Vitamins, by H. C. Sherman, Professor of Food Chemistry, Columbia University, and S. L. Smith, Specialist in Biological and Food Chemistry, United States Department of Agriculture. American Chemical Society Monograph Series. 273 pages, illustrations, 8vo. New York, The Chemical Catalog Company, Inc., 1922. Price, $4.00 net.

Practical Electrical Engineering. Direct Currents. A manual for use in industrial and evening schools and for home study, by Harry G. Cisin, M.E., Engineering Editor, *Electrical Record.* 324 pages, illustrations, 12mo. New York, D. Van Nostrand Company, 1922. Price, $2.00.

Elements of the Differential and Integral Calculus with Applications, by William S. Hall, E.M., C.E., M.S., Professor of Mathematics in Lafayette College. Second edition, revised. 250 pages, illustrations, 8vo. New York, D. Van Nostrand Company, 1922. Price, $2.75.

Éther ou Relativité, par Maurice Gandillot. 84 pages, 12mo. Paris, Gauthier-Villars et Cie., 1922. Price, 4 francs 50.

La Théorie de la Relativité et ses Applications a l'Astronomie, par Emile Picard, Secrétaire Perpétuel de l'Académie des Sciences. 27 pages, 12mo. Paris, Gauthier-Villars et Cie., 1922.

L'Éther Actuel et ses Précurseurs (Simple Recit), par E. M. Léméray. Préface de L. Lecornu, Membre de l'Institut. 141 pages, 12mo. Paris, Gauthier-Villars et Cie., 1922.

Carnegie Institution of Washington: Researches of the Department of Terrestrial Magnetism, volume iv. Land Magnetic Observations 1914–1920, by L. A. Bauer, J. A. Fleming, H. W. Fisk and W. J. Peters and Special Reports. J. A. Fleming: Construction of Non-magnetic Experiment Building of the Department of Terrestrial Magnetism. H. W. Fisk: Dip-needle Errors Arising from Minute Pivot-defects. S. J. Barnett: A Sine Galvanometer for Determining in Absolute Measure the Horizontal Intensity of the Earth's Magnetic Field. J. A. Fleming: Results of Comparisons of Magnetic Standards, 1915–1921. 475 pages, illustrations, plates, quarto. Washington, Carnegie Institution, 1921.

American Telephone and Telegraph Company: Annual Report of the Directors to the Stockholders for the Year Ending December 31, 1921. 44 pages, illustrations, 8vo. New York, Company, 1922.

Fundamentals of Economical Plumbing: Being Suggestions Made in June, 1921, to Secretary Hoover's National Building Code Committee in the Interest of the Betterment of the Housing Situation by Wm. Paul Gerhard, C.E., Dr. Eng. 4 pages, quarto. Reprinted from *The American Architect—The Architectural Review,* December 21, 1921. Price, 30 cents.

Sanitation and Sewage Disposal for Farmsteads and County Estates, by William Paul Gerhard, C.E., Dr. Eng., Consulting Engineer, Member, American Public Health Association. 12 pages, 8vo. New York, Author, no date. Price, 30 cents.

National Advisory Committee for Aeronautics: Technical Notes, No. 83, The Theory of the Screw Propeller, by A. Betz. Reprinted from *Die Naturwissenschaften*, 1921, No. 18. 12 pages, illustrations, quarto. No. 84, New Data on the Laws of Fluid Resistance, by C. Wieselsberger. Taken from *Physikalische Zeitschrift*, 1921, vol. 22, 12 pages, illustrations, quarto. No. 85, Air Force and Three Moments for F-5-L Seaplane by the Aeronautics Staff, Construction Department, Navy Yard, Washington, D. C. 13 pages, quarto, No. 88, Surface Area Coefficients for Airship Envelopes, by W. S. Diehl, Bureau of Aeronautics, U. S. N. 5 pages, illustrations, quarto. Washington, Committee, 1922.

Paving Costs. (*U. S. Department of Agriculture Press Service No. 195.*)—Average costs per square yard of various types of paving for country roads have been compiled by the Bureau of Public roads, United States Department of Agriculture. The figures cover 68,000,000 square yards of paving constructed with Federal aid in all parts of the United States during the period 1916–1921. The costs per square yard are as follows: Sand-clay, 18 cents; gravel, 46 cents; plain and surface-treated macadam, 95 cents; bituminous macadam, $2.10; bituminous concrete, $2.50; plain cement concrete, $2.57; reinforced-cement concrete, $2.74; and brick, $4.10.

These figures cover only the cost of the paving; they do not include the cost of grading, and officials point out that it must not be assumed that roads of the several types can be constructed in any locality at these figures. For example, the cost of bituminous concrete varied from $1.70 in the New England States to $3.13 in the group of States including Kentucky, Tennessee, Mississippi, and Alabama. In one group of States the cost of brick dropped to $2.40. Costs of constructing these types in the various groups of States have been compiled and can be obtained from the Bureau.

Railroad Ties and Weather Reports. (*U. S. Department of Agriculture Press Service No. 195.*)—The relationship between railroad ties and weather reports would seem to be rather distant, but a report received by the Weather Bureau of the United States Department of Agriculture from one of the large railroad systems of the West shows that the rainfall charts prepared by the Bureau saved this railroad a large amount of money.

During the war this road was unable to get creosote and had to substitute zinc chlorid as a preservative for ties. The zinc salt is a satisfactory preservative in dry climates, but where the rainfall is heavy it leaches out. When the war ended this company had on hand 2,500,000 ties that had been given the zinc treatment. Instead of re-treating them with creosote, the engineers secured a Weather Bureau chart and transferred the lines of average precipitation to a map of the system. Then they distributed the zinc-treated ties for use on those parts of the road in relatively dry regions.

CURRENT TOPICS.

Dispersion in Water of Electrical Waves of Lengths from 1240 to 600 mm. K. IWANOW, Sofia. (*Ann. d. Physik*, No. 14, 1921.)—Using a method devised by A. R. Colley the author determined the indices of refraction of electric waves in water. By means of a special type of vibrating system the waves are set up. The positions of the nodes, both in air and in water, were determined by a Geissler tube and from them the wave-lengths and the corresponding indices were calculated. We are accustomed to seeing the value of the index given as about 1.33, while in this paper its value lies in the vicinity of 9, but it should be remembered that the waves here employed are much longer than those of the visible spectrum. Colley had previously discovered a range of wave-lengths from 600 to 666 mm. in air through which the index does not change. Iwanow has found an additional range with the same characteristic, from 1188 to 1240 mm. The indices are respectively 8.974 and 8.998. Expressed in a different way this means that these two groups of waves, one of which is twice as long as the other, have about the same speed in water, just as red and violet light have the same speed in air or vacuo in spite of their travelling through glass or water with different speeds.

When light of the visible spectrum passes through a glass prism the red has the greatest speed and the speed grows less in going from one color to another toward the violet. Any such regularity of change is, however, lacking with the waves now under consideration. From 1240 to 1188 mm. wave-length there is no change of speed, as has been said, *i.e.*, the index of refraction does not vary. Then with a slight decrease of wave-length there comes a sudden lowering of speed which is succeeded by an equally abrupt increase which continues until a greater amount than the first is reached. Then there come decreases and increases quite regularly spaced until seven such variations have manifested themselves. After this still further toward smaller wave-lengths there comes an irregular set of increases and decreases until 660 mm. is attained, where for a range to 600 mm. the speed remains constant. Such optical comportment indicates anomalous dispersion, such as is produced by sending light through a prism of fuchsine, where the violet is less deviated than the red. In the case of cyanine R. W. Wood has found a variation of index similar to those described in the case of water. Drude had long ago discovered anomalous dispersion in the case of certain liquids. The effect of changes of temperature on the index of refraction also was investigated. As temperature goes up the index goes down. For example, for a wave-length of 630 mm. in air the

value of the index at 4° C. is 9.3 and at 90° C. is 7.56—no inconsiderable change.

These investigations were carried out at the University of Warsaw before the war. In making his acknowledgments to A. R. Colley, whom he designates as "this talented physicist and my best friend," the author adds that "he died a terrible death as a victim of civil war."

G. F. S.

Polarization Phenomena in X-Ray Bulbs. S. RATNER. (*Phil. Mag.*, January, 1922.)—"In the course of some experiments with an X-ray bulb through which a continuous discharge was maintained for a long time, the writer has observed a gradual hardening of the bulb in spite of the maintenance of a comparatively high pressure. Further experiments carried out in this direction have revealed a remarkable effect which takes place in an X-ray bulb or, more generally, in any vacuum tube after a sufficiently long and constant run. This is, that after a discharge has been kept running long enough, a time arrives where the resistance of the bulb begins to increase gradually, and finally becomes sufficiently high to stop the discharge altogether, although the pressure remains constant and comparatively high. This phenomenon is somewhat analogous to the polarization of an electrolytic cell." The time required to polarize a tube was in one case a small multiple of twenty-four hours. Then a potential difference of 50,000 volts caused no discharge in the tube though the pressure was as high as .035 mm. "A few hours later the minimum pressure at which the same potential difference could produce a discharge was of the order of .060 mm." Upon reversing the direction of the current it passed readily through the polarized bulb. Left to itself over night a polarized bulb by morning had become normal.

Now as to the causes of the polarization. The gases in the tube are not responsible, for when air is introduced into a polarized tube the phenomenon persists, and the effect develops even while a tiny stream of air is admitted during the passage of the discharge. Even more convincing is the fact that, after polarization has set in, a much lower voltage will cause a discharge between a pair of electrodes in a side tube where the gases present are of necessity the same as in the main tube. The introduction of a little water vapor will promptly reduce the polarization. The author sums up thus: "Now, internal changes in the electrodes could hardly be caused by the discharge, and it seems more likely that the phenomenon is due to the destruction by electronic action of the gaseous layers in the surface of the electrodes. These layers, whose existence is now well established, play an important part in various phenomena. It has long been well known that gases occluded in the electrodes greatly facilitate the passage of a discharge through a vacuum tube, and it has

been found recently that metal surfaces carefully freed from gases do not exhibit any appreciable photo-electric effect. It seems therefore, as if the process of electronic emission from cold metal surfaces could take place only through the intermediary of the surface-layer of gaseous molecules." G. F. S.

Wider Highway Tendency Shown in Road Building. (*U. S. Department of Agriculture Press Service No. 194.*)—Of 6500 miles of completed Federal-aid road for which statistics have been collected by the Bureau of Public Roads, United Stats Department of Agriculture, one-half has been constructed of 16 and 18-foot width, 25 per cent. of a greater width, and 25 per cent. of a less width. As would be expected the wider roads have been constructed largely in the more populous States, although some of the less populous States are building wider roads for the main highways. There is a general tendency, it is said, to build wider roads to meet the needs of the constantly increasing traffic, as shown by the 25 per cent. of the mileage over 18 feet in width, 7 per cent. being 24 feet or wider.

Wider Bridges for Roads. (*U. S. Department of Agriculture Press Service No. 193.*)—Few highway bridges with a width of roadway less than 18 feet are now being constructed on improved roads, according to engineers of the Bureau of Public Roads of the United States Department of Agriculture. In the past some of 12 feet and a good many of 16-foot width have been constructed in an effort to economize but it has proved short-sighted economy. Only one line of traffic can pass over a 12-foot roadway and 16 feet of width will not accommodate two lines in safety. Many of the States such as Pennsylvania, New Jersey, Ohio, and Massachusetts have found it advisable in replacing old bridges on important roads to make them wide enough to accommodate three and four lines of traffic.

PRESS OF
J. B. LIPPINCOTT COMPANY
PHILADELPHIA